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of the

American Welding Society

May, 1929

Published Monthly
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International Congress of Steel Construction

At Liege, Belgium, 1930, in Connection with the

INTERNATIONAL EXPOSITION OF LEADING INDUSTRIES, THE SCIENCES AND THEIR APPLICATION, AND ANCIENT WALLOON ART

*Celebrating the Centennial of Belgian Independence, with the Cooperation of the Belgian Government and Under the Patronage of the King.**

American engineers, steel manufacturers and others interested are invited to participate in an International Congress of Steel Construction in Liege, Belgium, and to present papers or to contribute to the discussions. Likewise, suggestions about the program, if sent soon, will be welcomed. Intention to participate should be made known promptly so that future bulletins may be seat to the persons interested.

General Program

1. Materials: Quality of Steel; Factor of Safety and "Fatigue" Limit.
2. Shapes: Standardization; Shapes of Large Dimensions.
3. Connections: Riveting; Welding.
4. Prevention of Corrosion.
5. Wind Pressure on High Buildings.
6. Examination of Existing Steel Structures.
7. Special Structures: Evolution of Bridges; Vierendeel Beam; Various Types of Movable Bridges; Aeronautical Hangars; Mine Timbering.
8. Various: Theories; Sheet Piling; Coffer Dams; Arches; Reservoirs; Pressure Conduits; Lock Gates; Sluice Weirs; etc.

The organizing committee appeals to foreign specialists to send papers on problems which they have studied, besides becoming members of the congress. The committee suggests that through the initiative of groups of engineers and manufacturers, national committees be formed with the object of organizing participation, in collaboration with national engineering societies. Each national committee is requested to designate a reporter for each division of the general subject, who will stimulate the preparation of papers, collect and forward them. Each reporter will be expected to summarize the contributions from his country on his division of the subject, and to send the papers and reports to the Executive Committee in Belgium. A general reporter for each division will later be appointed, who will present a collective report to the congress and start discussion. By effective organization and the careful preparation of papers, the central committee hopes to avoid loss of time in sterile recitals and to conserve time at sessions for discussion of the papers. Papers will be furnished in printed form in advance.

The Executive Committee would like to receive the papers and reports by September, 1929, so as to insure printing and distribution well in advance. The four days of the congress will be some time between August 15 and September 15, 1930. The official languages will be English, French and German. Papers will be published in their original languages, but the summaries probably in all three languages.

In order to receive the preliminary publications of the congress, intending members should send the fee of 35 belgas (approximately $5) to Congres International de la Construction Metallique, 4 Place Saint Lambert, Liege, Belgium, together with a registration in the following form:

Full name .....
Profession or business .....
Full address .....

*This statement condensed from the Belgian manuscript invitation, in French.

registers for the Industrial Congress of Steel Construction at Liege in 1930. He intends to participate in the activities of the Congress ..... He is especially interested in the following subject: .....

Signature.....

Date.....

A rooming service will be organized. There will be interesting excursions and social features. Ladies are invited and their visit will be made enjoyable.

Americans are urged to collaborate in this congress because of their notable achievements in structural steel.

Engineering Standards for Society*

GEORGE OTIS SMITH†

The distinction between science and engineering is a difference both in purpose and in method. It is the sharp contrast between theory and practice; it marks the broad gap between dream and attainment. You remember the old saying that "where there is no vision the people perish"; translate this into modern experience and we may say that "where there is no science, the engineer fails."

There are, then, two torch-bearers in this never-ending relay race: one lights the torch of science in eternal truth and uses it to fire the imagination; the other carries the same torch still onward and uses it to kindle the fires of industry and commerce and to illuminate the pathway of human progress. It will be a sad day for mankind when either of these torch-bearers fail to do his part—when scientific research lags behind or engineering practice does not carry on.

As I view the new outlook of engineering I cannot subscribe to the century-old definitions which restrict to the resources of Nature the application of science by the engineer. In its subject-matter, engineering is more human than mechanical. Not only does engineering have human welfare at its very center, but in its expanding field it touches humanity at all points on its circumference.

Time is one of the counters by which the engineer measures success. He realizes that saving time is saving human energy, whether that energy is being currently expended as labor or has been stored up in what we call capital. Increasing the wattage of human energy without raising the voltage too high is the task which human engineering sets itself: in other words, making the workman more effective with fewer hours of work and under less rather than more pressure—that is true conservation of human energy.

It is a commonplace of the changing standards of living that the wage earner of our day can command luxuries which were beyond the reach of kings a generation or two ago. Adding power to the human arm and making it more productive is what characterizes modern industry; the carrying of heavier loads at higher speeds, making the ton-mile faster and cheaper, measures the success of transportation as we know it; and the conquest of distance, making the whole world one neighborhood, is the outstanding triumph of modern communication. All this marvelous progress is simply an exhibit of what engineering by the application of science has wrought in adding cubits to the stature of man.

With civilization running at high speed, there is increased need of devoting the best talent to public welfare. To this end, the great National Engineering Societies may well assume a larger responsibility in keeping America in a condition of preparedness to meet the demands of peace. The burdens of prosperity are already so heavy as to tax to the utmost the genius of engineers.

I have come to look upon the National Engineering Society as a public utility—a chain of interconnected central stations, generating useful currents of thought and distributing this service over large areas. Here is an open forum, a much needed forum, where facts may be presented regardless of what they prove and where opinions may be expressed irrespective of their bearing upon conservative corporation practice or static Government policy.

Even in this enlightened year of 1929 the economies of the steel plant have not penetrated the market place, and the high efficiency of the creators of our electrical equipment is not

*Reprinted from "Proceedings of the American Society of Civil Engineers," April, 1929, Part 2.

†Past-president, American Institute of Mining and Metallurgical Engineers; director, U. S. Geological Survey.

copied by those who control our city governments. Is not the lesson obvious that engineers are needed in economics and politics? As applied to Government, engineering will mean using fewer officials to do the present amount of work or doing more work with the present force. Many terms in common use by the engineers—such as obsolescence or elimination of waste or even simplification of practice—are unknown to the politician or at best are pronounced by him only with difficulty. Another job for the matter-of-fact engineer in the field of industrial economics is to take some of the psychology out of the business cycle, that resultant of the forces of Nature and of human nature—both of them proper subjects for engineering control.

You engineers know the facts better than the economists, and you are less hampered by reverence for economic theory, much of which is the worse for wear and should soon be replaced by something up to date. Engineers use facts not as pieces on a chess-board to be moved back and forth in a contest of wits, but rather as foundation stones to be assembled where needed and arranged in a fixed and logical order.

Elimination of waste is essentially an engineering problem, whether that waste takes the form of unmarketed crops or of uneducated children, of rust, or of graft, of decay in timbers, or of rottenness in public officials.

I would, therefore, urge the adoption of the engineering type of specifications even for intangibles. In our thoughtful discussion of the deeper and the higher things of life, how often engineering terms creep into our language—firm foundation, stress and strain, factor of safety. The realities of life call for just such strong words. Might it not be well in our day to take over into our business, social, and even political life not only these engineering terms but more of what lies back of them—the technique, the principles, the mental attitude of the engineer; in short, his engineering standards.

"Machines and the man" would be the opening words of the epic written by a Virgil of this industrial age—and "the man" he would sing is the engineer. It is the engineer who has given to the world of industry a new momentum; he it is who can best chart the trend of the new social order.

Fall Meeting

American Welding Society

The Fall Meeting of the American Welding Society will be held in Cleveland, September 9 to 13. In addition to our own meetings, there will be meetings of the American Society for Steel Treating, the Institute of Metals Division, the American Institute of Mining and Metallurgical Engineers, the Iron and Steel Division of the American Institute of Mining Engineers and the Iron and Steel Division of the American Society of Mechanical Engineers. The 11th National Metal Exposition will, of course, be held in conjunction with these meetings.

SECTION ACTIVITIES

Boston

The Boston Chapter of the American Society for Steel Treating held a Joint Meeting with the Boston Section of the American Welding Society on April 5, 1929. They first visited the plant of the Bethlehem Shipbuilding Corporation, Ltd., at Quincy, Mass. The program was as follows:

2 p. m.—Registration at Employment Building. Plant visitation, welding demonstrations and ship inspection.

4 p. m.—Presentation of motion pictures in Assembly Room by the American Welding Society.

6 p. m.—Dinner in main dining room.

7.15 p. m.—J. R. Dawson, metallurgical engineer of the Union Carbide & Carbon Research Laboratories, spoke on "Fusion Welding."

Chicago

On Friday, April 5, the Chicago Section of the American Welding Society

met in the Engineering Building, Wacker Drive and Wells Street, Chicago. A paper on "Arc Welding as Applied to Machinery and Structural Erection" was presented by A. M. Candy, of the Westinghouse Electric & Mfg. Company.

The meeting was opened with the presentation of a two-reel film, "Asbestos, the Magic Fiber," presented through the courtesy of the Johns-Manville Corp. This was a most interesting film, indicating the manufacturing processes used in preparing this material for a wide variety of applications.

In presenting his paper, Mr. Candy outlined the wide use and application of the welding processes in industry today. In developing his subject he pointed out that in using arc welding advantageously in machinery construction and also structural steel erection that the designers needs must forget entirely the principles formerly used in preparing machinery for cast construction. In showing the feasibility of this particular point, Mr. Candy indicated many of the new designs which have been successfully developed and used by his own company in making generators and motors. In many cases he pointed out where very material savings had been made in material used, in the time of construction and in addition there was obtained a much stronger and lighter unit when completed.

Mr. Candy then enumerated many of the bridges and steel building structures that have been erected successfully throughout the country with the arc. Illustrating his points with slides, he pointed out where steel erection in the future is going to make wide and successful use of arc welding.

The meeting was one of the best attended during the year. Many of those registered indicated that steel fabricating concerns are developing more than a passing interest in the application of arc welding to their work.

Philladelphia

On Monday evening, April 15, the Philadelphia Section held a very successful meeting. J. W. Meadowcroft, assistant works manager of the Edward G. Budd Manufacturing Company, gave a talk on "Welding Used Extensively in the Production of Sheet Metal Products."

San Francisco

A rather unique program was enjoyed by the members of the San Francisco Section on the evening of March 28. The meeting was held at the Central High School in Oakland, and the program put on by the members of the welding classes of that school with the cooperation of S. H. Edwards, metallurgist for the Industrial Service Company. The first part of the evening was devoted to the operation of gas and arc welding equipment by the students, comprising a group of adult trade extension students and a group of younger students of school age, who are being trained for an advantageous entry into the welding industry.

The meeting was called to order in the school auditorium and for forty minutes Instructor C. A. Britton put the boys of the younger group through their paces in a way which left no doubt in the minds of those present that the boys are not only receiving a thorough training in the practical use and care of welding equipment and knowledge of related subjects, but are also taught the value of basic economic and industrial principles which make for better citizens and better employees. One significant feature of the training is that each student is firmly impressed with the fact that when he leaves the school he is NOT a welder, and will have to go through a period of service "on the job" before he can qualify as a welder.

It is the purpose of the Central High School to establish relations with welding concerns in the bay district which will make possible an apprenticeship training period for these young men, under a definite time period and a definite training schedule, as is the case in the trades of plumber, machinist, sheet metal worker, etc.

Mr. Edwards ably illustrated his address with drawings on the blackboard, taking up the subjects of strains and stresses set up in steel under uneven heating and cooling, and the nature of changes in the crystal structure of steels with varying heat treatments and the introduction of special alloys.

It may be safely said that "a good time was had by all."

Testing Resistance Welds*

By J. W. MEADOWCROFT†

REGARDLESS of the external appearance of a welded joint there are occasions when it becomes desirable to investigate the quality of the weld from every possible angle. The manufacturer who is using welding as a production process must satisfy himself that his product is perfectly sound before putting it on the market. The microscope is a valuable instrument for investigating metal structures because it tells many things which are not seen with the naked eye and often explains the data obtained from physical tests.

Resistance welding calls for careful control methods because when the method is once put into operation its production possibilities are tremendous, consequently the work done by resistance welding machinery has often been subjected to the searching scrutiny of the microscope in order to make sure that this huge volume of work would be as satisfactory in quality as in economy.

In order to have a definite piece of work to use for an example which might serve as a suggestion as to how to use the microscope in examining other products, a wire auto wheel in which the spoke was welded to the rim was selected. The position of the microphotographs is indicated in the sketch shown in Fig. 1. You will note that the end of the spoke was swaged to shape, leaving a small cavity in the end—a part of which remained unfilled after the welding operation. The drawing also indicates the exact outline of the union between the spoke and the rim. It may be seen that the spoke has been slightly pressed into the rim. It appears that in welding the spoke was held by a collar of some sort and that a plunger then pressed on the rim in much the same way as our method of spot welding.

Microphotograph No. 920 shows the typical structure of cold drawn low carbon steel wire. In this picture, the direction of drawing runs parallel to the bottom of the page, as evidenced by the slight elongation of the grains.

Microphotograph No. 919-C of the rim shows the typical structure of a low carbon steel.

Microphotograph No. 919-A is part of the same spoke as No. 920. The regular orientation of the grains indicates that the heat produced during the welding operation has partially removed the effect of cold work, i. e., produced a partial annealing of the spoke.

It may be seen in microphotographs No. 919-B and No. 919-D that these areas contain a higher percentage of carbon than the original steels.

*Laboratory work by Jos. Winlock, Metallurgist, Edw. G. Budd Mfg. Co.
†Assistant Works Manager Edw. G. Budd Mfg. Co.

We have an equally interesting but somehat less complicated program of inspection when we use the microscope to investigate the flash welding of sheet steel in the very light gages. During the past twenty years much has been accomplished in the various methods of resistance welding of sheet metal with the spot, roller and butt welding. However, very little stress was placed on the flash welding of light gages of sheet metal due to the difficulty in controlling the expansion and contraction of light gage sheet steel.

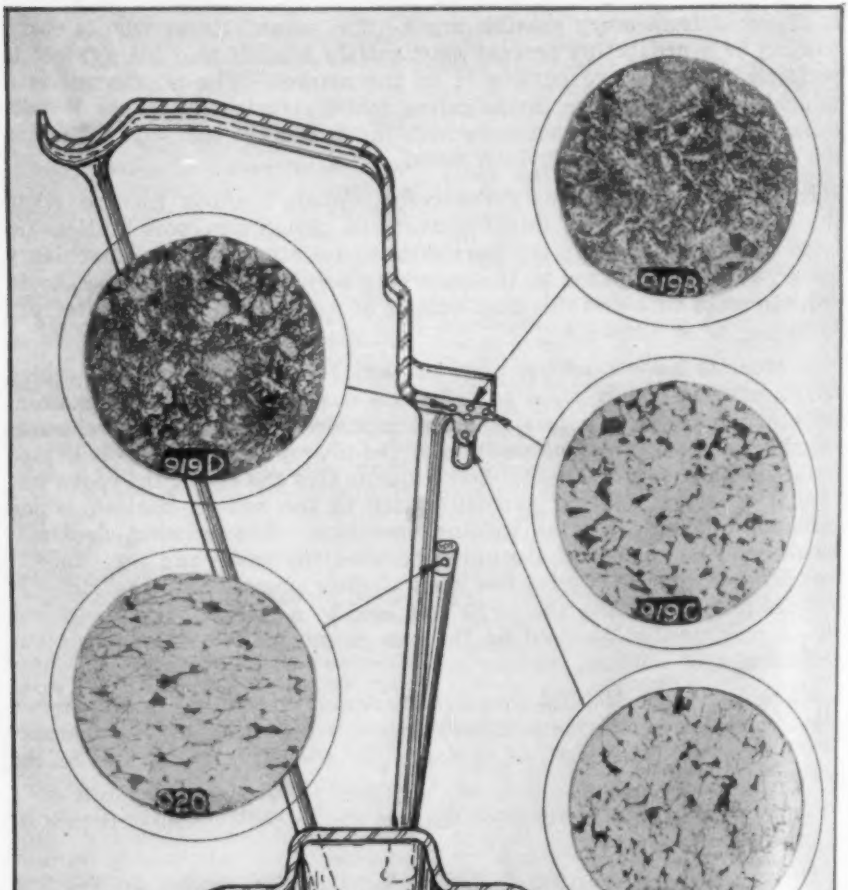

FIG. 1

Mr. F. P. McBerty found, in his experiments, that it was possible to flash weld four joints at one time, and developed a machine for flash welding four corners of sedan automobile door panels. The joints were each 2¼ in. long.

Mr. A. C. Taylor began his experiments about the same time and developed a four-way machine for flash welding window frames for automobile doors.

FIG. 2. COWL FLASH WELDED

Neither Mr. McBerty nor Mr. Taylor stopped with this development but experimented with machines for flash welding sheets of steel .040 to .050 in. in thickness and developed the machine so that today it is being used commercially to flash weld joints from 12 in. to 57 in. long, on cowls, tonneaus and side panels for automobile bodies, and many other commodities. One of these machines was described in a recent issue of the *Welding Engineer*.

Cowls are made in two pieces and are flash welded on top at the center line of body. A section is blanked out of cowl after welding for ventilator opening and cowl is then formed at this point. The joints on cowls are 16 in. long and are welded at a rate of 60 welds per hour on each machine.

To give a thorough understanding of this method of welding Fig. 2 shows a photograph of a cowl, flash welded, on a flash welding machine, with microphotographs of welded metal in joint and on each side of

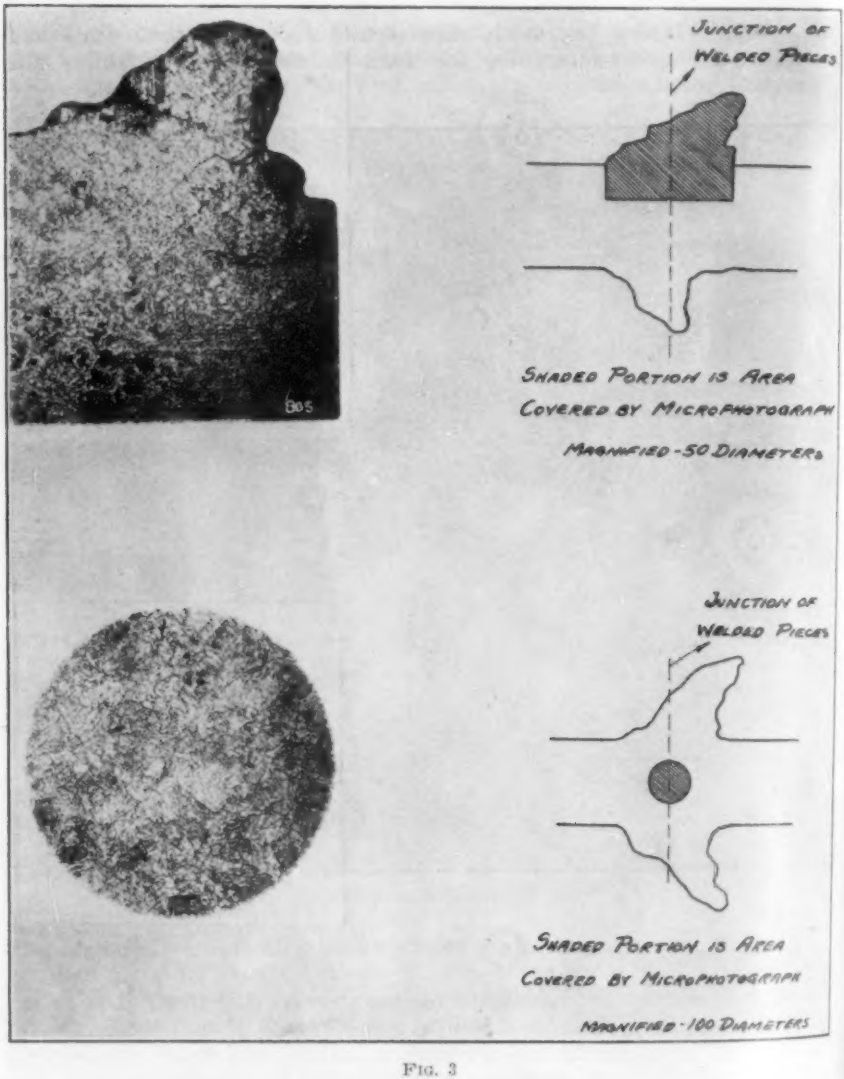
JUNCTION OF WELDED PIECES
SHADED PORTION IS AREA COVERED BY MICROPHOTOGRAPH
MAGNIFIED - 50 DIAMETERS
JUNCTION OF WELDED PIECES
SHADED PORTION IS AREA COVERED BY MICROPHOTOGRAPH
MAGNIFIED - 100 DIAMETERS

FIG. 3

joint shown in Fig. 3. As these investigations would indicate, the flash welds are very ductile and can be chipped, filed or ground, the outer surface of weld being somewhat hard but not sufficiently to cause unnecessary wear on chipping tool, files or emery wheels. No difficulties are encountered in blanking out and forming the welded sections.

Hospital Addition Erected Silently

A. F. DAVIS†

IN Wheeling, West Virginia, surgeons, physicians and nurses attend their patients in the Ohio Valley General Hospital undisturbed by the erection of steel framework for the new addition to the present hospital building. There is no rat-a-tat-tat from the riveting hammers reverberating through wards, clinics and dispensaries—the electric arc fuses member into member, silently. Fifteen feet from the operating table a welding operator strikes an arc, welds beam to column while muzzled white-frocked surgeons perform their delicate tasks in quietness.

One hundred forty beds will be added to the hospital when this new six story, quarter-million dollar addition is completed. The present building forms three sides of a square, one side being six stories high, the other two sides five stories high. The new addition encloses a court, and brings all sides of the hollow square up to a height of six stories. The building was designed by architect Charles W. Bates of Wheeling, and is being erected by R. R. Kitchen & Company of the same city.

While the shop fabrication of the structural steel is of riveted construction, the electric arc welding process was used to make all field connections, the members being held prior to welding by field bolts. The illustration, Fig. 3, shows a typical beam to column connection. The intermittent fillet welds which secure the webs of the beams to the column take the place of connecting angles. This eliminates considerable shop and field fabrication, which would have been necessary to make such a connection of riveted construction.

Another interesting detail of welded construction is the splicing of columns, as shown in Fig. 4. The splice plates were riveted in the shop to the lower column section. About two-thirds of a splice plate was used to make the riveted connection which required six rivets. The remaining or upper third of the splice plate was punched for two field bolts which hold the upper section in place, while fillet welds were run around the edges of the splice and filler plates fusing them into the flanges of the upper column section. The photograph, Fig. 4, also illustrates the method employed in connecting the exterior beams and tie beams to the exterior columns. Intermittent fillet welds 3 in. long tie the 15 in. I-beams into the columns.

Where openings occurred in the exterior walls lintels to span the top of openings are welded to the bottom of the exterior beams, as shown in Fig. 5. To secure the plate lintels to the beams by the traditional riveted method would have required considerable more laying out, in addition to punching the beam flanges and plates and driving the rivets. By the use of C clamps the lintel plates were held in position while one

†Vice-President, Lincoln Electric Co.

FIG. 1. THE OHIO VALLEY GENERAL HOSPITAL, WHEELING, WEST VIRGINIA. THE STEEL STRUCTURE OF THE NEW ADDITION WAS ERECTED SILENTLY BY ARC WELDING

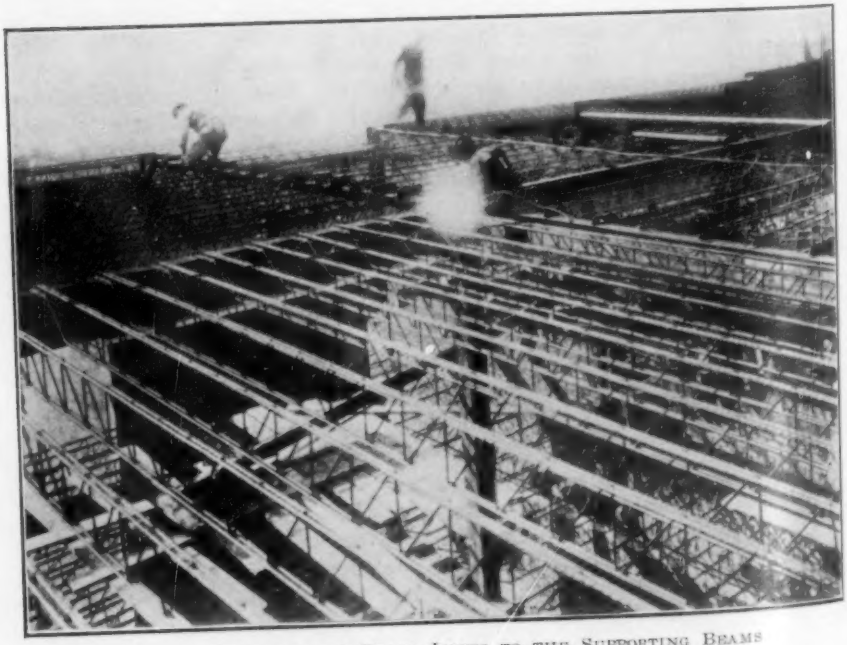

FIG. 2. WELDING THE FLOOR JOISTS TO THE SUPPORTING BEAMS

welder operator fused steel into steel with the electric arc in one-third of the time required for riveted fabrication.

Welded bar joists are used to carry the 2-in. concrete floor and roof slabs. These joists are welded in place at each end to their supporting beams. This improved method of securing the floor joists gives increased stiffness to the entire structure. To give the joists increased lateral stiffness a $\frac{3}{8}$ in. rod is laid across the bottom chords of the joist in the center of their span and welded to each joist. This increases the rigidity of the joists to a far greater extent than if they were bridged in the usual way with wire.

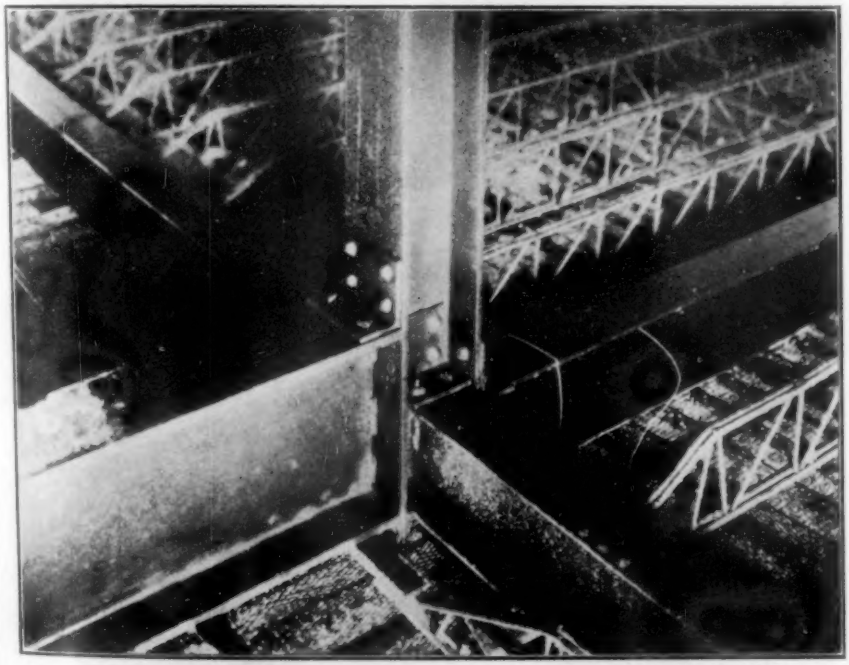

FIG. 3. DETAIL OF ARC WELDED BEAM TO COLUMN CONNECTIONS

The 150 tons of structural steel required for the framework of the new addition was erected by the general contractors. Two portable motor-driven welders of 300 amp. capacity were used to supply the current for welding.

While this steel structure is not entirely arc welded, due to the shop fabrication being of riveted construction, it represents an intermediate stage of design in steel structures between the traditional all-riveted construction and the modern all-welded construction. Mr. R. R. Kitchen, head of the construction company which bears his name, estimates that the cost of arc-welded steel erection will not exceed, and in the final analysis may prove to be even less, than the cost of a field riveted job.

Such results obtained from actual practice should encourage those who have been a trifle skeptical of the strength and economies of all-welded steel construction to attempt to obtain at least a few of the advantages which the new method offers. The use of a combination of riveted and welded construction will give experience and promote confidence in the electric arc-welding process. As experience and confidence is gained the use of welded construction will increase until the transitional stage between riveted and welded construction will have ended and the efficient modern all-welded steel construction will be recognized as standard practice.

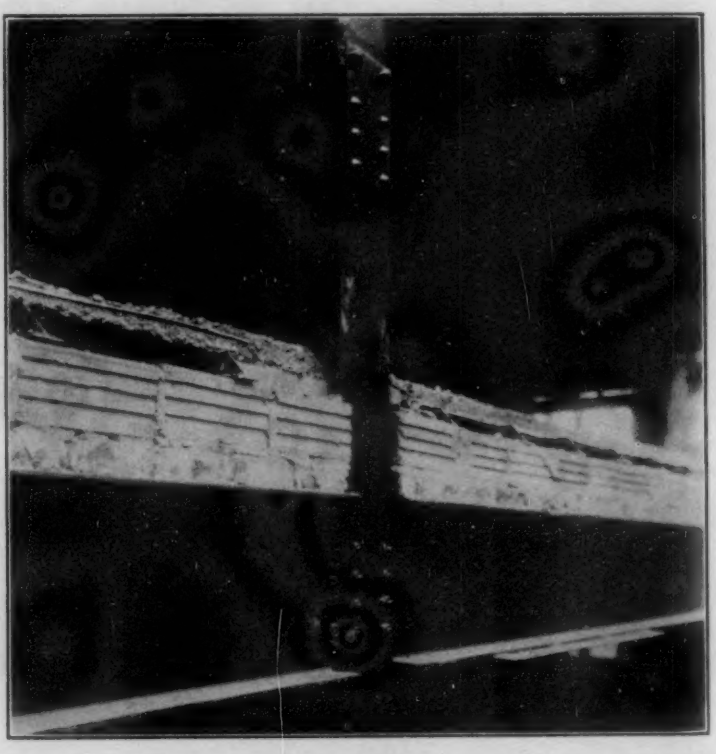

FIG. 4. DETAIL OF COLUMN SPLICE AND EXTERIOR BEAM TO COLUMN CONNECTIONS

Heretofore the cost of additions to department stores, office buildings, hospitals, hotels, telephone exchanges and similar buildings has not been reckoned solely by the actual cost of labor and material but has by the force of necessity included the cost of the loss of business incurred due to the disturbing noise created by the field riveting of structural steel. In many cases this loss has exceeded the actual labor and material cost of the building. Since the introduction of the electric arc welding process into the field fabrication of structural steel this loss of business during building operations has been reduced to a negligible amount due

solely to the silent erection of steel which has been made possible by arc welding.

Illustrative of the value of silent erection is an incident experienced during a visit to the scene of building operations at the Ohio Valley General Hospital. An abdominal operation performed by two surgeons was carried through to completion in almost absolute silence while only 15 ft. away a welding operator was making beam-to-column connections

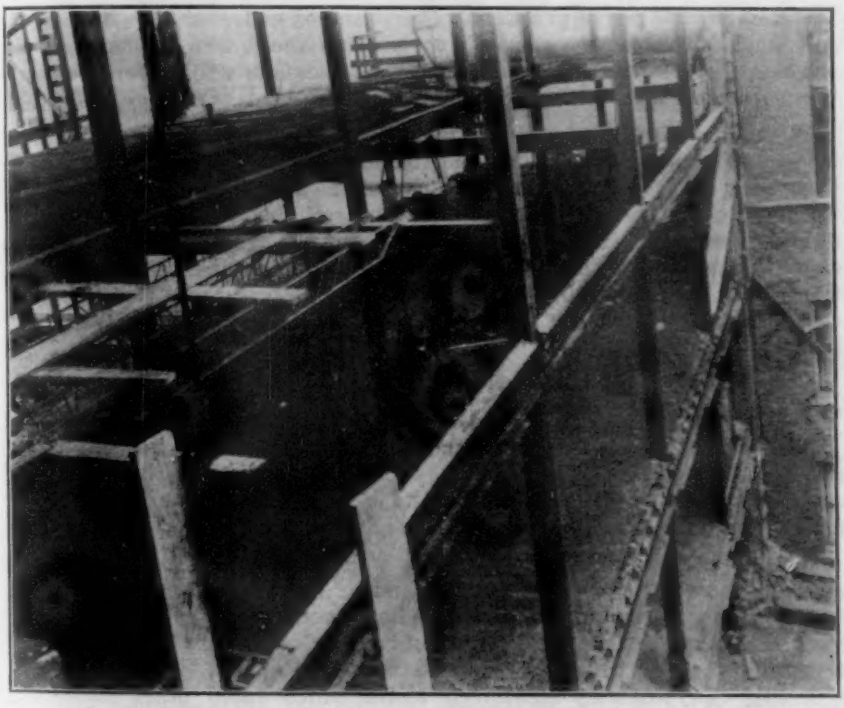

FIG. 5. LINTEL PLATES WERE ARC WELDED TO THE BOTTOMS OF THE EXTERIOR BEAMS

with the electric arc. Dentists occupying offices in the Rose Building, Cleveland, Ohio, have filled teeth while within a few feet of their open windows welding operators fused steel to steel with the electric arc. Such delicate tasks could not have been performed during building operations if riveted construction had been employed. Taking into consideration the immeasurable value of silent erection, arc welded steel construction offers an economy that cannot be approached by any other method of joining steel.

Detailing of Welded Steel Buildings*

By E. C. Brown†

NEW departures in practically every line of endeavor have inevitably met with resistance, particularly from those who are engaged in the line of work in which the departure is made and who prefer to adhere to former methods.

When the first wrought iron nail was introduced the "doubting Thomases" implored the people not to permit their use and the "powers that were" to legislate against the use of the iron nail in any structure, the plea being, first, that the nail was not reliable except in part, when it was possible to clinch; secondly, because the elements would soon cause its deterioration, and, thirdly, and by no means the least objection, that lightning would surely be drawn by these "iron pegs" and so cause destruction of life and limb; further, the old "wooden key" or "trennel" would always suffice.

Even as late as the early eighties, this "lightning bogy" was with us when steel frame structures first began to appear.

Another objection raised was the allegation that steel was too brittle and even after steel was introduced for main members, a good many of us can still remember the iron rivets, and it took a long time for the steel rivet to become generally acceptable.

We are now beginning to face the welded structure, which is most essentially a child of the present day and this welded structure is traveling the same thorny path of its immediate predecessor, but its advocates have the same patient determination and spirit, which spells the one word that applies to this form of structure, namely, SUCCESS, that overcame the obstacles mentioned above which faced other forms of metallic construction.

You have seen the welded factory buildings of the Trafford City Plant of the Westinghouse Electric & Manufacturing Co., the second largest structure of the welded type in the United States and in the writer's opinion there will be many more coming in the immediate future.

The details of this structure were prepared by the writer from general plans by Bernard Prack. The steel was furnished by the Jones & Laughlin Steel Corp. and the field welding and erection was done by Minnotte Brothers Company.

In the detailing of this work there were many points developed, some of which may be interesting. The main material was ordered, cut to length and shipped direct from the mill to the job. This material

*Presented before the Pittsburgh Section of the American Welding Society, January, 1929.

†E. C. Brown, Engineers.

had the usual mill variations and was marked with an item number on each piece for identification in the field and, in addition, the detailed material that had shop work, such as base plates, base angles and connections, were also given an essembly mark.

The fitters on the job assembled and clamped this material together from the shop bills and detail drawings, after which the ground welding was done. Column slabs, where light, were welded to the column shaft prior to erection. The heavier slabs were welded to the columns after erection. For the latter type clips were ground welded to the columns to take the anchor bolts so that the columns could be held in position without waiting for the welding of shafts to the base slabs.

The beams were detailed with a connecting angle welded to the top flange at each end so as to maintain an accurate overall length and to insure the proper spacing of the columns to which they connect. A seat angle was welded on the columns to take the reaction from these beams and after the beams were placed the beams were welded to the seat angle and the top connecting angle welded to the column, thereby making a stiff connection.

The bottom chord struts between the trusses were detailed with a small plate or bar, welded to the web of the strut at each end, this plate or bar being notched so that it would drop over the vertical leg of the angles constituting the bottom chord of the trusses, this holding it in place until field welding could be done.

The use of welded connections simplified these details as there were no gauge lines for holes and if necessary for a beam to be set off center it could readily be done, using the same detail as if it had been required on the center of the column. In riveted work seat angles vary every time a gauge is changed, adding considerably to the complications of detailing.

As you have noticed, there are very few holes in this work except for the connection of what may be called "companion materials," and the only bolts used on the job for connecting steel to steel were for fastening purlins to trusses and window struts to columns.

In all, there are four buildings embraced in this operation. Building No. 1 is 60 ft. wide by 140 ft. long; has three floors and roof, with an offset 20 ft. by 75 ft. of the same height as the main building. Building No. 2 is 60 ft. wide by 300 ft. long, with a four-story offset 20 ft. by 40 ft. Building No. 3 is 100 ft. wide by 460 ft. long, the two end bays of which compose the office building, this office building being two stories high. Building No. 4 is 57 ft. wide by 132 ft. long and has a five-ton crane runway.

With the exception of the offsets and the office building, the roof construction consists of trusses with monitors and channel purlins, the purlins of the office building being the J. & L. junior beams, as is also the case with the offset roofs. A walkway runs the full length of the inside of all monitors for the use of window cleaners. The walls are of brick and windows have steel sash, the trusses being from 20 ft. to 55 ft.

above the ground level. Spandrel beams in general consist of beams with plates to carry brickwork and with window angles.

The total tonnage for all the buildings is approximately 875 tons.

The instructions received at the time of undertaking this detailing were as follows: There was to be no punching of main material except crane girders for rail clips, window supports for sash and for purlins.

No bolts were to be used except where erection would be exceptionally difficult and for purlin connections.

No welding was to be done in the shop but all welding was to be done at the site.

No overhead welding was to be done.

All material to be ordered shipped direct from the mill to site, unless punched, cut or milled. All punching, cutting and milling was to be done at the shop.

The details of beams framing to columns and girders were to be so made that they would automatically space the columns and could be easily clamped into position, regardless of any cutting variation.

Erection diagrams were to show position of beams, etc., in their relation to column centers and floor lines.

These instructions were adhered to in the detailing of this work.

It is needless to say that placing a job of this size and character in a drafting room with the above instructions gave us some new problems to solve, as there were no leads available except a small amount of literature on welded structures, and which described the various tests and the precedents set by riveted work; and while good, were by no means always applicable.

The natural tendency of structural draftsmen, by training and years of experience is to visualize all connections and joints as riveted, and it was necessary to overcome this tendency to a certain extent, for while the general conditions were similar to riveted work, the immediate requirements made it necessary to develop from these general conditions a welded job that would be satisfactory. From your observance this afternoon you may judge for yourselves how close we have come to carrying out this work properly.

The first actual work done in the drawing room was the ordering of main material, the major problem here being to decide whether the material should be ordered shipped to the shop or direct to the site.

In writing the order bill the material was noted on the margin as to where it was to go and an item number was assigned to all material for identification, this item number being painted on all pieces marked as "shipped to the site," as this was the only readily available means of identification that could be used. There was a further use for this item number, which will be explained later.

In preparing the details, the fact that all welding was to be done at the site made it necessary to devise a system whereby all members of

any particular piece could be identified and assembled. This was no small task, as can be gathered from the fact that the number of pieces to be handled was about 26,000 and which varied from bars 2 in. x ¼ in. x 3 in. up to 24 in. beams 55 ft. long.

Except for the trusses, all details were made on sketch sheets measuring 12 in. x 24 in. and the component parts of each piece, be it a beam, column or truss that was fabricated in the shop, was given an assembly mark, which mark was followed by the sheet or drawing number that was used as a shipping mark and listed alongside of the detailed sketch as shop material, and the parts that had been shipped direct from the mill were listed as "field material" and carried the item numbers previously mentioned as appearing on the mill orders. In this way it was easy for the drafting room, shop and the field man to tell at a glance from the detail drawings from what source the material would come.

The types of details used were seat angles and top clips, so far as possible, and where this was not sufficient a bar was welded to the end of the beam, which in turn was welded to the supporting member, making what in riveted work would be called a "web hitch." Where two beams of the same depth framed together, the web of the connecting beam had a bar welded to the web which, in turn, was welded to the web of the header beam and a bar was welded to bottom flange of main beams, extending out about 2 in., for a landing seat; but where the header beam was deeper a seat angle was welded at the proper height. Spandrel sections and other light compound members were fastened together with tack welds, about 12 in. centers; these tack welds being about 1 in. long.

The detailing of the trusses on this work required considerable study as the chords were composed of two angles and both angles must take their share of all stresses. To do this the web members had to be connected to both angles to properly distribute their load. Gusset plates were used only at the heels of the trusses and a small reinforcing plate was used at the peak. Clips for connecting purlins were welded to the rafters, the outstanding legs of these clips being punched to receive purlins. The knee braces were punched with one hole at each end to receive drift pins for lining up the structure. Continuity for floor beams and purlins was obtained by continuity plates or bars on the top flanges over supporting members and welding in of bottom flanges to the supporting members to take the corresponding compression.

In specifying the welding, ¼ in. fillets were specified on all material ¼ in. thick and 5/16 in. fillets were used elsewhere with a few exceptions where heavier welds were required.

Great care was taken to properly distribute the welds over the connections so as to insure rigidity to the welded connection when completed.

In assembling the trusses the bottom chords and rafters were assembled and welded separately, these chords and rafters being afterward put together in jigs so as to be held in proper position, after which the web members were put in place and the entire truss, including monitor frame, welded up into one piece. When this was done the truss was taken off the welding skids and placed to one side until the time came to put it in the building.

In giving dimensions for these trusses all dimensions were given to the backs of angles instead of to gage lines as is customary on riveted work, the reason being that this gave the fitter a definite point to which to work, and in the assembly clamps were used for holding the material together preparatory to welding; and there was developed great ingenuity, as in spite of all efforts, many details were found that would be difficult to hold with the ordinary commercial clamp that is available in the market.

A 200-Mile Welded Pipe Line

B. S. HAVENS†

A PIPE line 205 miles long, running from Jal, N. M., to El Paso Tex., is now being electrically welded. This pipe line, 16 in. in diameter, will carry gas for the El Paso Utilities Company, and is being installed by Smith Brothers, Inc., general contractors.

The electric arc welding of the entire pipe line is being done under the direction of Messrs. Fred Clark and F. G. Hoffman. A total of 27 welding sets are in use, some mounted on Fordson tractors and driven by the tractor engine, and others mounted on trucks and trailers.

The pipe, in 30-ft. sections, is strung along the cleared right-of-way. Seven of the 30-ft. lengths are then lined up, making a section approximately 200 ft. long. One welding crew fixes the sections temporarily in position by tack welding and another completes the welds.

The tack welding machines are self-propelled equipments, as the first welding crew is often some distance ahead of the men who complete the welding operation. The pipe is turned, as the welding progresses, by one man using long-handled tongs. Every seventh joint is an expansion joint. This consists of a short piece of pipe with upset corrugations. This joint adds flexibility to the pipe as well as allowing for expansion and contraction when in use.

After the 200-ft. sections are completed, another crew lines them up with the completed pipe line, using a caterpillar tractor and boom. As the pipe cannot now be turned, the welds are made by the "bell-hole" method, in which the operator moves his own position to weld all sides of the pipe, making the weld on the lower side from an excavation dug beneath for that purpose.

By the use of 3/16-in. diameter welding electrode and a current of approximately 175 to 190 amperes, the greatest welding speed consistent with the highest quality weld is obtained. Each operator is able to make approximately 13 welds in ten hours.

After the final welding operation is completed, the joints are tested and then treated with a corrosion resisting compound, after which the pipe is lowered into the ditch.

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†Publicity Department, General Electric Co.

Structural Welding From the Standpoint of Building Departments*

G. F. EMERY†

THIS paper is designed to express to welding engineers and those interested in the promotion of welding the attitude of Municipal Building Inspection authorities on the use of welding in building construction and is necessarily limited to a consideration of the use of welding on the structural elements of the building as differentiated from its use for purely ornamental or other unessential features.

Welding as a method of rigidly connecting or joining metallic pieces is of ancient origin, but due to a lack of knowledge and development, has not been applied to building construction until comparatively recent times. The use of welding on building construction has awaited the development of satisfactory and reliable methods and equipment for application and has been forced by economic conditions which necessitated the use of special methods to secure the special advantages inherent in a construction of this kind.

When structural welding is considered by the building official, he is compelled to refer to his Building Code or other ordinances which outline the duties of the Department and designate the authority and powers which are delegated to him. He immediately discovers that not only are there no provisions contained therein governing this method of construction but also that it is not even mentioned and he is therefore compelled to refer to those sections governing acceptance and approval of materials and construction not specifically covered by various articles of the Code.

Building Codes in general represent the expression, in ordinance form, of the police power of the municipality to regulate matters pertaining to buildings from the standpoint of public safety, and are necessarily largely based upon the accumulated custom and precedent of the past.

Inasmuch as structural welding is a comparatively recent application still in the development stage, sufficient experience and tests are not yet available for standardization, and for this reason it is not feasible as yet to amend Building Codes in such a way as to cover all angles of this important subject.

In view of the apparent success of welding for manufacturing processes, the construction of machinery and other equipment and its many desirable features for building construction, most Building Departments have tacitly permitted its use when confronted with the necessities pre-

*Presented before Pittsburgh Section, A. W. S., Jan. 1929.
†Chief Building Inspector, Department of Buildings & Safety Engineering, Detroit, Mich.

sented on some unusual job, under all the safeguards which could be thought of, and with excessive factors of safety. Consequently the attitude of Building Departments has been that of not encouraging its use in structural work, but rather discouraging its use unless some special advantage or necessity was present so that the situation could not properly have been taken care of by any other means.

The use of structural welding has been found very desirable on the construction of additions to existing buildings or other types of connections where difficult or impossible to make by any other means and on the reinforcement of existing structural members.

As more welding has been used in work of this kind and has been found satisfactory and reliable, more tests became available, and the attitude of the department has become more neutral toward its use. However, it soon began to appear that there was a considerable variation in the practice of welding as applied by welders and welding companies and also some diversity of opinions among architects and engineers as to proper methods of design when using this type of connection. It therefore became necessary that some preliminary standard be formulated and adopted governing the use of welding which would not unduly hamper its development, would permit its use where necessary or desirable, and at the same time carry out the necessary function of the building department to obtain the safety of construction.

The Building Department must consider a number of important aspects when formulating requirements of this kind. The requirements must be practical, complete and definite and be workable from the standpoint of design, construction and inspection. In considering the relation of the use of structural welding on a building from the Department's viewpoint, it is of course essential that the structure and its connections be properly designed so that sufficient welding is specified and the type of connections is such that it can properly be applied in the field.

The preliminary plans showing the welding should therefore be submitted to the Department and checked and approved by the examining engineers before construction work is started on the job in the field. After the plans have been filed and approved, it will be assumed that the job of welding begins and the responsibility shifts to the field forces of the Department where the actual construction must be supervised and inspected.

The data which are used in drawing up a regulation of this kind are largely secured from tests made by and at the instigation of the Department and by the reports of other competent investigators. A sufficient number of tests covering every possible variation in conditions should now be available so that proper values for allowable stresses can be definitely established. Necessarily, these allowable working stresses where assigned will involve a somewhat higher factor of safety than that used in other types of steel construction which are fully standardized, but as experience proves the uniformity and reliability of welding, these factors of safety can no doubt be reduced to a point comparable to those recognized in other types of connections.

In permitting the use of welding, it is important that the responsibility of the welding contractor be definitely fixed and that only welding contractors who have the proper experience and equipment to carry out the class of work involved, be permitted to do structural welding. The contractor being acceptable, it is essential that the workmen on the job be conscientious and skilled so that having the proper materials and equipment to work with, the right sort of welding will be produced on the job.

The permissible kinds of welding must be specified as arc welding, gas welding, spot welding, etc., although at present there does not appear sufficient experience, knowledge or tests available to justify permitting the use of any process other than arc welding on building construction.

The plans and specifications which are to be submitted to the Department for approval must show the complete structural lay-out and framing of the building together with sufficient details so that proper consideration can be given to the design by the examining engineer. The plans and specifications must specify the amount of welding to be supplied for a given loading and this welding should be specified in terms applicable to field construction. This necessarily means that for all welding connections, the size of fillet or bead must be designated together with the number of lineal inches. The structural plans should show the reactions given by each beam or girder or the stresses which the welded connection is expected to transmit. The specifications should outline the equipment which it is expected that the welding contractor will provide on the job, the size and quality of the welding rod which is to be used and the amperage at which the work is to be carried on. When proper plans, as above specified, have been carefully examined and approved and are complete in all essential respects, the work of the field inspector is greatly assisted and the first step has been taken toward securing a safe and reliable job.

The inspector is given the responsibility of seeing that the welding is supplied as required by the plans and specifications and that the work is carried on in complete conformity to the regulations which are given him to enforce. The field inspection of welding, is, of course, largely a visual operation, but an experienced and capable inspector can satisfactorily inspect welding work in this manner. Having assured himself that the equipment provided is of proper character and capacity for the work being done and that the welding rods are of proper size and character, he must determine that the welder understands his business and can successfully carry on the type of work at hand. He must ascertain that the size and amount of welding complies with the approved plans and that the welds as laid down on the work are sound and uniform, without oxidation and porosity, and have sufficient penetration. The objection is often raised that it is impossible to determine the quality of the weld by its external appearance, but experience has shown that a capable man can quite easily identify a satisfactory or unsatisfactory weld by the local pecularities present on the surface of the weld. This same objection was advanced against the use of reinforced concrete construction when that material was first being used but experience

proved that tests could be made which would give a reliable indication of the quality and strength. The same principle can be applied to structural welding and periodic tests can be made of test coupons produced on the job under field conditions which will give reasonably good assurance that satisfactory work is being turned out.

Having considered all of these essentials which are important to the proper regulation of welded building, a tentative bulletin has been drawn up intended to fulfill these requirements. It has been intended to secure what we believe to be reasonable standards of design, construction and inspection with adequate safety under present conditions. It is, of course, subject to revision and improvement as means of betterment are discovered or defects are pointed out. The bulletin follows herewith.

Proposed Structural Welding Regulations

Fusion welding may be used for all or part of the joints and connections of structural steel constructed under these specifications in place of bolting or riveting provided such welding is made in accordance with the following requirements.

Each person, firm or corporation desiring to use welding shall apply to the Department of Buildings for such permission, shall comply with all the requirements herein, and receive approval from said Department before any welding on structural steel is done.

The Department shall authorize the use of fusion welding on structural work in all cases where these requirements are observed and reasonable assurance is given that the welding will be properly executed. The applicant for such authority shall furnish a written statement giving the type of welding, equipment to be used, the names and experience of their welders, and a certified laboratory report of the tests of six coupons, submitted directly from the testing laboratory.

The Department shall have the power to require additional test coupons and tests whenever doubt shall arise as to quality of work done by any welder, previously authorized to use welding.

Detail plans of all welding work on structural steel must be submitted and approved by the Department of Buildings before any actual work is begun. These plans shall include specifications, details of connections and loads thereon and a schedule showing amount of welding, size of fillet beads, length of fillet beads and spacing edge to edge of beads. The Department must be notified by post card or phone call when any field welding is to be commenced so that proper inspection can be made.

1. Fusion welding as defined in these regulations shall consist of welding done by the electric arc process. The processes of welding known as oxy-acetylene and electric spot welding shall not be used on structural work.

2. Structural welding shall be done by competent welders with not less than two years' experience in field or shop welding. The ability of the welder shall be proven by the making of test coupons as previously specified.

3. Test coupons shall consist of two pieces of 2 in. x ½ in. steel bars, 9 in. long, beveled at one end to 45 deg. The beveled ends shall be placed together and a weld made in the notch to the thickness of the bars. This welded specimen when tested in a tensile testing machine shall either fail outside of weld or if in the welding at a load of not less than 40,000 lb. The coupons shall be made under normal working conditions by the welders who are to carry on the work using regular equipment and materials.

4. All welds shall be of fillet or button type. In the fillet type no bead shall be less than ¼ in., nor more than ½ in. with a minimum length of 2 in., made with one single continuous pass of the electrode, and crater shall be outside the required length of weld. In the button type, the hole to be plugged with weld metal shall not be less than 1 in. in diameter or of greater depth than ½ in. the diameter of the hole. Where fillets are used the outside of bead shall be convex rather than concave.

5. The minimum thickness of any material to be edge welded with fillet shall be ¼ in. and with button welds ⅜ in.

6. Surfaces to be welded must be thoroughly cleaned before welding and must be free of scale, rust, dirt and paint or other foreign substances which interfere with the proper fusion of the metal. Surfaces formed by burning with oxy-acetylene cutting torch shall be chipped clean of scale and burned metal before these surfaces are welded.

7. The amperage and voltage used on electric welding shall be properly adjusted to the size and type of welding rod and character or work to give a uniformly sound weld with sufficient penetration and prevent oxidation and porosity.

8. Welding rods for electrodes shall conform to the American Welding Society's specifications for such material.

9. For purposes of design the allowable working stress for fillet welds may be assumed at 1600 lb. per linear inch for ¼ in. bead, 2400 lb. per lineal inch for ⅜ in. bead and 3200 lb. per lineal inch for ½ in. fillet. The sizes and lengths of welds are limited to values given in Section 4.

10. The allowable working stress for button, plug or fillet welds may be taken as 9000 lbs. per square inch of minimum effective cross section for shear, tension or compression.

11. Welded shear connections shall be designed in such a way that they will have sufficient flexibility or shall be designed with requisite strength to develop any moment that may be imposed upon them without over-stressing the welds.

12. The Structural Steel or other accredited Inspectors of Department of Buildings shall have power to condemn and order removed and replaced or reinforced, any welding contrary to these regulations and to the approved plans, or in their opinion defective, unsound and unsafe.

All parts of these regulations as pertaining to design and making of welds are hereby made immediately effective, but the requirement of registration of persons, firms, or corporations engaged in this work will not be placed in effect until sixty (60) days from date of issuance of

these regulations, by which time, all applications for registration must be made and approved.

It is of course very desirable that welded construction be recognized and covered by Building Codes and ordinances but this does not seem possible or practical until practice in the art becomes stabilized, and sufficient tests, experience, and knowledge of its use under every conceivable condition have become available so that definite and permanent standards can be established. It appears very probable now that refinement and improvement of methods of welding will result in stronger and reliable welds which will justify a reduction of the factor of safety.

As to the future of structural welding, it seems to possess great potentialities. It is apparently the only method of producing rigid joints in articulated structures so as to cause all members to act as a homogeneous and coherent whole. Its use offers an opportunity to the structural designer to utilize more fully the strengths available in structural steel which at present cannot be fully utilized. In certain situations, welding seems to be not only desirable but essential to give an acceptable construction. As instances of this, we might mention the anchorage of steel joists to steel supporting members, the lateral bracing of steel joists by cross bars in top and bottom chords and the attachment of caps and bases on pipe columns. The proper and complete application of welding connections in structural design, however, requires that the entire design be made with a view to the use of this method, and all connections be detailed to assume every advantage of the rigidity or economy which can be secured from the use of welding.

The American Welding Society, through its meetings, tests, and publications, has alreay accomplished a great deal toward the development of structural welding and its application to buildings and no doubt this organization can through the resources at its disposal standardize the art of structural welding to a point where it can be accepted by Municipal Building Codes on a basis comparable with other established and recognized methods of construction.

Discussion of Mr. G. F. Emery's Paper on "Structural Welding from the Standpoint of Building Departments"

G. D. FISH†

MR. EMERY'S broad and comprehensive outlook on this new method in steel building construction should be an inspiration to building superintendents generally.

His conservative position regarding kinds of welding, types of welds and working stresses to be permitted is entirely reasonable in view of

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the comparative novelty of the method and the degree of responsibility that rests on a building department in preventing dangerous methods and poor workmanship in city building construction.

The building code clauses on structural welding recently completed by the Committee on Building Codes of the American Welding Society permits the use of working stresses about 25 per cent higher than those in Mr. Emery's proposed clauses, and permits the use of butt welds as well as fillet welds. Furthermore, it admits gas welding on a par with electric welding. There is a great deal of weighty evidence in favor of these more liberal provisions, and it is to be hoped that building codes throughout the country will be extended to recognize welding in building construction in accordance with provisions of the American Welding Society's code. It is a difficult matter to change an existing law so as to permit higher working stresses than are already named in the law, and it is to be expected that trouble will be encountered in changing working stresses for welds in any code which may be adopted instead of the American Welding Society's code. A difference of 25 per cent in the amount of welding required for a given job is a serious cost item, and inasmuch as the safety factors provided by the higher working stresses are larger than the safety factors used in the design of the structural steel members themselves, it would seem that they are conservative enough.

Butt welds are less common than fillet welds in structural framing, mainly for the reason that they are usually more expensive. The cutting of members to extra length and beveling them in preparation for butt welding are expensive processes, and in case of very heavy butt welding the amount of weld metal required for a given duty is generally in excess of that required for equivalent fillet welds. Nevertheless, there are cases where butt welding is essential in order to make the most direct and compact joints possible, and there seems to be insufficient reason for discriminating against them.

Mr. Emery indicates that fillet welds should be convex rather than concave. There are reasons for preferring fillet welds with plain exposed faces to those which are either concave or convex. A concave weld is weaker than one with a plain surface, but this in turn is not weaker than a convex weld, or not appreciably so. Convexity wastes metal and therefore time, and has a definite disadvantage in that it makes more difficult the work of the inspector in determining whether the edges of the fillet show overlap; a weld which is very convex is apt to have an appearance of overlap at the edges even if thorough fusion has been accomplished.

Mr. Emery's remarks regarding feasibility of making satisfactory inspections of welds are quite in line with the experience of designing engineers and steel contractors' engineers who have seriously taken up structural welding. If the practicability of determining the soundness of welding by means of visual inspection were generally recognized there would be nothing except common problems to retard the general acceptance of welding in place of older methods in steel construction.

Specifications for Welding Steel Buildings by Electricity*

General Applications — Definitions — Materials — Apparatus — Permissible Unit Stresses—Workmanship—Qualification of Welders—Proportion of Parts—Protection of Steel

FRANK P. MCKIBBEN†

Section 1: GENERAL APPLICATION

(a). Arc welding may be substituted for or used in connection with rivets or bolts, or other methods prescribed in the Standard Specifications for Structural Steel for Buildings adopted by the American Institute of Steel Construction as amended to date, for connecting together or assembling the component parts of beams, girders, lintels, trusses, columns or other structural steel used in building construction.

Section 2: DEFINITIONS

(*a*). *Arc Welding*

The process of using the electric arc to join steel parts in the molten, or molten and vapor states, without the application of mechanical pressure or blows.

(*b*). *Arc Weld*

A weld in which the welding heat is generated by an electric arc formed between the base metal and the electrode, or between two electrodes, with or without the use of hydrogen or other equivalent gas.

(*c*). *Electrode*

A specially prepared metal wire or rod used as a terminal in an electric circuit to produce an intense heat by means of the arc, and which may or may not supply the molten steel required for joining the parts to be welded.

(*d*). *Filler Metal*

The metal which is added to a weld by the melting of an electrode or a welding rod.

(*e*). *Weld Metal*

The material composing a weld.

(*f*). *Base or Parent Metal*

The material to be welded.

(*g*). *Fillet Weld*

A weld, at the intersection of two surfaces approximately at right angles to each other, in which the weld metal has a triangular cross-

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section, its two sides being the original surfaces of the base metals, and its third side the exposed hypothenuse.

The size of a fillet weld is expressed in terms of its length and width, the latter being the dimension of the side of the largest isosceles triangle contained in the cross-section of the weld metal.

(*h.*) *Butt Weld*

A weld joining the edges of a butt joint in which two members are brought together edge to edge but not necessarily in contact, one surface of each member being in the same or parallel planes.

(*i*). *Continuous Weld*

A weld of unbroken continuity used for strength or tightness, or both.

(*j*). *Intermittent Weld*

A strength weld consisting of a series of short welds in line, alternating with unwelded spaces.

(*k*). *Tack Weld*

A short weld used not for strength but for purposes of assembling only.

Section 3: QUALITY OF MATERIALS

(*a.*) *Structural Steel*

The steel used in structures covered by these specifications shall be of the grade designated as "Structural Steel for Buildings," as specified by American Society for Testing Materials, Serial No. A9, as amended to date.

(*b*). *Electrodes and Welding Rods*

The wire used for electrodes, or the welding rods, shall be commercial mild-steel wire made for this purpose, of uniform homogenous physical structure, and free from irregularities in surface, from hardness, segregation, foreign matter, oxides, pipes, seams, or other defects.

Welding wire made from steel produced by the puddling process shall not be used.

The diameter shall not vary more than 0.003 in. above or below the nominal values.

In the hands of an experienced welder, electrodes and welding rods shall show good welding qualities in flat, vertical, or overhead positions, and shall pass through the welding process without exhibiting any unusual characteristics.

The chemical compositions shall conform to the limits given in Table I for uses specified.

Wire of Grade A shall be used for hand arc welding; and Grade B for automatic machine arc welding.

Section 4: APPARATUS

(*a*). The arc-welding apparatus shall be of standard design and be the product of a reputable manufacturer.

(*b*). The welding current shall preferably be direct current supplied by generators driven by electric motors or engines having suitable auto-

matic speed regulation. Whether for use in hand or machine welding, the generators shall be adjustable for different current values and shall deliver constant current at suitable voltage for each setting of the regulator.

Section 5: PERMISSIBLE UNIT STRESSES

(*a*). The welded joints shall be so proportioned that the combined dead and live loads, and impact, if any, shall not cause the stresses therein to exceed the following amounts in *pounds per square inch:*

Shear on minimum section of weld metal.....11,300
Tension of minimum section of weld metal.....13,000
Compression of minimum section of weld metal.....15,000

(*b*.) The maximum fibre stresses due to bending shall not exceed the values prescribed in paragraph (*a*) for tension and compression respectively.

(*c*). The stresses in welded joints due to wind only, and combined stresses due to wind and other loadings, may exceed by 33 1/3 per cent the values prescribed in paragraph (*a*); provided the section thus obtained is not less than that obtained if the wind force be neglected.

(*d*). In designing welded connections allowance shall be made for bending stresses due to eccentricity, if any, except that in designing fillet welds no allowance need be made for the bending couple formed by resultant stresses on the two fused sides of the weld.

TABLE I

	Wire, Grade A, Per Cent	Wire, Grade B, Per Cent
Carbon	0.13 to 0.18	Not over 0.10
Manganese	0.40 to 0.60	0.25 to 0.45
Phosphorus	Not over 0.045	Not over 0.045
Sulphur	Not over 0.045	Not over 0.045
Silicon	Not over 0.06	Trace

Section 6: WORKMANSHIP

(*a*). The surfaces to be welded shall be reasonably cleaned of loose scale, rust, paint, or other foreign matter by wirebrushing, chipping, or hammering; except that a thin coat of linseed oil need not be removed before welding.

(*b*). The welding operators shall submit evidence of experience in welding structural steel with the kind of welding to be used on the proposed work, and show ability to make flat, vertical, and overhead welds of uniform quality conforming to the requirements of these specifications.

(*c*). After being laid, the welds shall be brushed with wire brushes, and shall show uniform sections, smoothness of weld metal, feather edges without overlaps, and freedom from porosity and clinkers. Visual inspection at the edges and ends of fillet-joint and butt-joint welds shall indicate good fusion with and penetration into the base metal.

(*d*). The arcs for electric welding shall be of proper lengths to produce good welds.

The same electrode may be used with various thicknesses of plate, but thicker plates require heavier currents.

(*e*). The current values to be used in hand welding are indicated approximately by the figures shown in Table II, which are intended as a guide to the operator who shall select the size of electrode and then adjust the electric current to produce good homogeneous welds of the foregoing characteristics.

TABLE II

Electrode Diameter in Inches	Ampere for Hand Welding	Corresponding Plate Thickness in Inches
1/16	50 to 75	Up to 3/16
3/32	75 to 100	Up to 1/4
1/8	100 to 150	Above 1/8
5/32	150 to 200	Above 1/4
3/16	175 to 225	Above 3/8
1/4	200 to 250	Above 3/8

(*f*). The current values for machine welding may exceed those specified in paragraph (*e*), but machine welding shall, if required, meet the same qualifications as specified for welders in Section 7.

(*g*). In assembling and during welding, the component parts of built-up members shall be held by sufficient clamps or other adequate means to keep the parts straight and in close contact.

(*h*). In welding, precautions shall be taken to minimize "locked-up" stresses and distortion due to heat.

(*i*). Before welding new steel to old, both shall be free from paint and other foreign matter, except that a thin coat of linseed oil need not be removed.

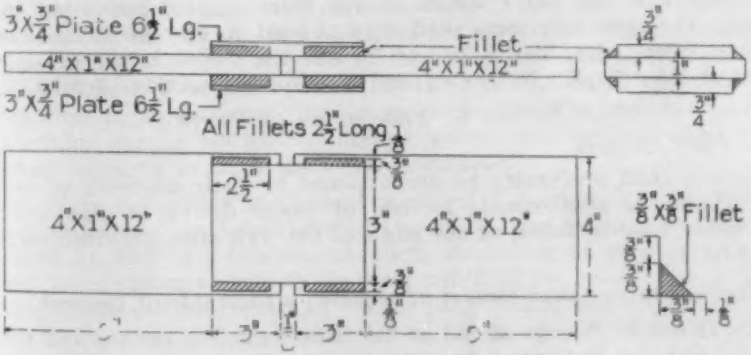

FIG. 1. TEST SPECIMENS FOR FILLET WELD

Section 7: QUALIFICATIONS OF WELDERS

(*a*). *Butt Welds*

The welders may be required to weld four sample butt joints each made of two pieces ½ in. by 9 in. by 12 in. to form a piece about 12 in. by 18 in., prepared with double Vee as specified in Section 8, paragraph (*f*); of these, two sample plates are to be welded in the horizontal or flat position and two in the vertical position with the joint located vertically.

Each sample plate shall be machined so that the joint is reduced to the thickness of the base metal. From each sample plate, standard two-inch tensile-test specimens shall be made and tested in tension, to conform with the American Welding Society standards. The average tensile strength of each group of five sample plates shall not be less than 45,000 lb. per sq. in., and the tensile strength of the lowest in each group shall not be less than 40,000 lb. per sq. in.

(*b.*) *Lap Welds*

The welders may be required to weld four sample lap joints each made of ½-in. by 6-in. by 8-in. plates clamped one on the other with the 8-in. edges lined up but with the 6-in. edges offset ½ in. A full ½-in. fillet is then to be made along one 6-in. edge in accordance with the specifications presented in Section 8, paragraph (*g*).

Upon completion of the welds and after cooling, the specimens shall be torn apart and broken by wedging at the unwelded 6-in. edges; and the fractured metal of the specimen broken through the weld shall reasonably show: bright, dense, even-textured, crystalline or fibrous weld metal, irregularly torn and void of iridescent colors; good fusion of weld and base metals; and good penetration into right-angle corner of the fillet.

(*c.*) *Fillet-Welds*

The welders may be required to weld three sample test specimens of the size shown in Fig. 1. In depositing the weld metal, all craters shall be filled to the full cross-section of the fillets. Electrodes of 3/16-in. diameter shall be used. These specimens are to be tested in tension to ascertain the longitudinal shearing value of the ⅜-in. fillet welds, and the fractured specimens shall be examined for penetration into the parent metals and for freedom of gas holes or slag inclusions in the fillets. The three specimens shall show at least an average ultimate longitudinal stress of 38,000 lb. per sq. in and the lowest in the group shall show at least 34,000 lb. per sq. in. of minimum section of fillet.

Section 8: PROPORTION OF PARTS

(*a*). *Plate Girders*

Girders shall preferably be proportioned by their moments of inertia, but where the approximate method of flange design is used the web equivalent may be taken as one-sixth of the web area, provided no holes exist in the web.

The web splices shall consist of a plate on each side of the web.

The stiffeners may be angles or flat bars, welded to the top and bottom flanges and also to the web by continuous or intermittent welds designed to transmit the stresses. The stiffeners at the bearings or other points of concentrated loading shall be fitted to the flanges.

The connection of component parts of girder flanges to each other and of flanges to webs shall be by continuous or intermittent fillet welds designed to transmit the stresses. Intermittent welds shall be not less than one and one-half inches long, spaced in the clear not exceeding 16 times the thickness of the thinnest piece connected, nor more than four inches in the clear.

Plug or slot welds may be used to fasten cover plates to other members.

(*b*). *Beams*

Continuous beams and girders designed in accordance with generally accepted engineering principles may be used, provided that welded connections be properly proportioned to resist bending moments to which they are subjected.

When the toe of a seat angle supporting a beam is to be welded to a web or to a column and is not truly formed, but is rounded due to worn rolls or other causes, either a preliminary fillet shall be deposited to fill the open space after which the full fillet required in the design shall be deposited, or the rounded edge of the toe shall be sheared square to receive the full fillet required.

(*c*). *Trusses*

For tension or compression members having symmetrical cross-sections, the fillets shall be arranged symmetrically about the axis of the member, or proper allowance shall be made for unsymmetrical distribution.

For members of unsymmetrical cross-section, like angles for example, the lengths of fillets shall be determined by taking moments about the gravity axis of the member.

(*d*). *Columns*

Built-up or rolled-steel columns shall contain no material, except filler plates, whether in the body of the column or used as lattice bars or stay plates, less than ¼ in. in thickness.

The ends of columns shall be faced to plane surfaces at right angles to their axes. Column splices, whenever practicable, shall consist of splice plates connected to the columns with proper amounts of fillets. When sections of columns to be spliced are such that splice plates cannot be used, connections may be formed of plates and angles or other shapes designed to distribute the stresses properly. In all cases, column splices shall be so arranged that by bolts or otherwise the various tiers of a column can be accurately aligned before welding, and shall be of sufficient strength to carry the erection stresses.

The fillets connecting component parts of a built-up column may be either continuous or intermittent, and if of the latter type shall be arranged as follows: Continuous fillets extending at each end of the column for a distance equal to the least width of the column; then intermittent fillets one and one-half inches long spaced not exceeding four inches in the clear for the remainder of the column's length.

Lattice bars and tie plates, where used, shall be welded with fillets to secure strengths equal to those of the rivets in lattice bars and tie plates connected by rivets as specified in the Standard Specifications for Structural Steel for Buildings adopted by the American Institute of Steel Construction and as amended to date.

(*e*). *Welding and Bolting*

For welding structures, connections of main members carrying live loads producing impact, and connections of members subject to alternate stresses, shall be welded.

For welded structures, component parts of all columns, girders, and trusses shall be welded with fillet welds.

For welded buildings over four stories high, all column splices and all connections of beams and girders to columns—or within three feet thereof—shall be welded.

Unfinished bolts may be used in the shop or field for connections of small structures used for shelters and for connections of secondary members of all structures, such as purlins, girts, door and window framing, lining up bracing, and filling-in beams in floors. In buildings two or more stories high, sufficient bolts shall be used to connect properly all members during erection.

So far as possible all joints shall be designed to eliminate overhead welding, and arranged so that the welds will be in shear or direct compression.

Tension butt welds shall not be used in main truss members, but may be used in secondary members, wind bracing connections, beam and girder connections.

To the calculated lengths of each weld, proper additions shall be made to allow for the crater.

Fillet welds of lengths less than four times their width shall not be figured as part of any connection.

(*f*). *Butt Joints*

All portions of members ¼ in. in thickness, or over, to form butt joints shall be beveled with either single Vee or double Vee, or their equivalents.

The steel for single Vee joints shall be beveled not less than 30 deg. on each edge to form an open angle of not less than 60 deg.

The steel for double Vee joints shall be beveled not less than 37½ deg. on each side of each piece to form open angles of not less than 75 deg.

In all single Vee and double Vee butt joints the beveled edges shall have initial free distances of ⅛ to 3/16 in.; and steel ¼ to 7/16 in. thick shall be welded in one layer; steel ½ to 11/16 in. in two layers, and ¾ to 1 in. in three layers.

All these joints shall be somewhat reinforced but not to exceed 20 per cent for single Vee or 15 per cent for each side of double Vee joints.

(*g*). *Lap Joints*

All lap joints in ¼ to 7/16-in. steel shall be fillet welded in one layer, ½ to 11/16 in. in two layers, and ¾ to 1 in. in three layers. The contour of the cross-section of the fillet shall be as near as practicable to a right triangle with equal sides, and with minimum side not less than the prescribed dimension of the cross-section of the fillet.

(*h*). *Drawings*

The drawings shall show clearly all welds, including the length and width of all fillets both for shop and field welding.

Section 9: PROTECTION OF STEEL

(*a*). The structural steel before being welded shall not be painted. If it is to be welded only in the fabricating shop and subsequently erected

by bolts or rivets, it shall receive in the shop one coat of acceptable metal protection after shop welding is finished, and one coat after erection. The steel to be field welded shall receive one coat of linseed oil after shop welding is completed; and after being erected and welded it shall receive two coats of acceptable metal protection.

No paint shall be applied to steel surfaces which are to be encased in concrete.

Weld Test of Heavy Column Joints Shows Good Results*

FOLLOWING a series of tests it made for the Port of New York Authority on values of rivets and bolts in tension on typical joints to be used in the Hudson River suspension bridge, the American Bridge Company on its own initiative straightened and welded the specimens

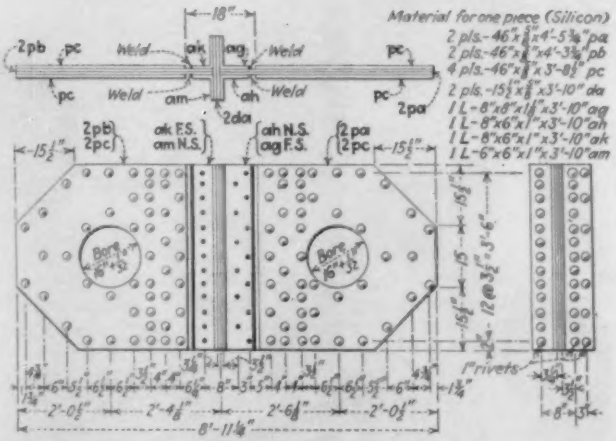

FIG. 1—WELDED TEST PIECE TYPICAL OF THE HEAVY COLUMN JOINTS WHICH WILL BE RIVETED IN THE HUDSON RIVER BRIDGE TOWERS

and retested them under the same conditions as used in the original tests. The results furnish excellent data on the strength of long fillet welds (two 46-in. fillets) in transverse shear.

The test specimen shown in Fig. 1, except for welding, represents a typical column joint to be used in the towers of the Hudson River bridge. The original tests made with the specimens completely riveted showed a maximum load of 950,000 lb., or 46,520 lb. per sq. in. of nominal rivet section. After these tests the distorted angles of the original specimens were straightened and the specimens fabricated as shown in Fig. 2. A

*Taken from March 7, 1929, issue *Engineering News Record*.

fillet bead 7/16 x ½ in. was deposited in two layers, using 5/32 in. electrodes with 175 amp. for the first layer and 3/16 in. electrodes with 205 amp. for the second layer.

The specimens after testing in a 2000-ton eyebar testing machine are shown in Fig. 3. The test results were as follows:

Test No. 1—Maximum load, 1,100,000 lb.; broke in weld, along *ag;* average width of weld fracture, 0.453 in.; total linear inches effective weld, 92; stress per linear inch weld, 11,950 lb.; stress per square inch weld, 26,380 lb.

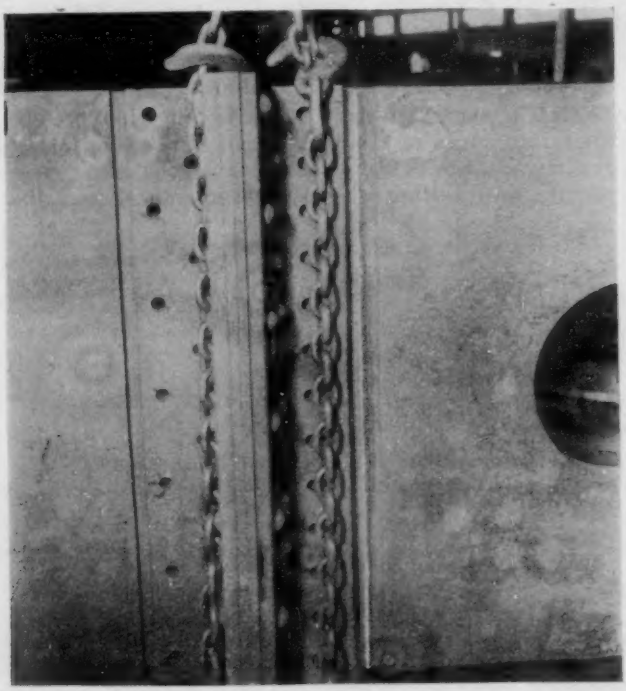

FIG. 2—WELD FRACTURE AT 11,680 LB. PER LINEAR INCH

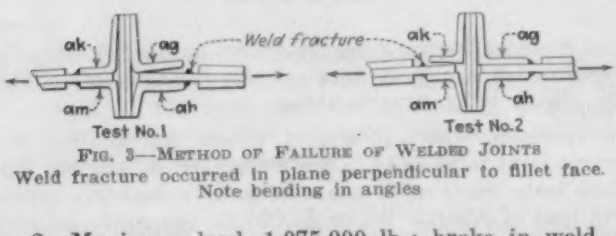

FIG. 3—METHOD OF FAILURE OF WELDED JOINTS
Weld fracture occurred in plane perpendicular to fillet face. Note bending in angles

Test No. 2—Maximum load, 1,075,000 lb.; broke in weld, along *ak;* average width of weld fracture, 0.416; total linear inches effective weld, 92 in.; stress per linear inch weld, 11,680 lb.; stress per square inch weld, 28.090 lb. per sq. in.

Abstract of a Paper on "The Application of Electric Welding to the Fabrication of Structural Steel and Ornamental Iron" *

PAUL B. COVEY†

IN the development of my subject I shall consider both structural steel and ornamental iron touching on each of the following eight operations entering into steel and iron construction—design, details, lay-out, assembly, tacking, welding, shipping and erection.

Design

As far as structural steel is concerned, the general design of framed structures will not vary materially whether welding is used or riveting except in so far as it may be possible to make use of the principle of continuity at connections. The great differences in design will come in the working out of the details as we shall see in a few minutes. Neither is there much opportunity for change in the general design of ornamental or miscellaneous iron work. Nearly all of the lay-outs of this class of work are made either from an architectural or a purely utilitarian standpoint and since in most cases there are no stresses occurring in any parts of the structures which require calculations, it is usually the case of detail design which governs the entire lay-out.

But when we get to the point of working up our design of details we find we are entering a brand new field of activity. There are no handbooks which can be referred to for "standards"—there are no rule-of-thumb methods to be followed—it is all new and different and herein lies one of the great appeals for the use of welding—the studying out of something new.

After the general stress diagram of a steel structure has been prepared, it is necessary to select the sections to be used for the various members of the framework. Of course, we all know of the saving of material possible through the use of gross section for tension members instead of net sections and I shall not dwell on that except to say that we have found from several comparative calculations we have made that the saving varies from around 10 per cent to 25 per cent depending upon the size and shape of the frame and upon the loads to be carried. The greatest saving will come, however, I believe, from a departure in many cases from our old accustomed sections to others more suited to the use of welding and much more economical.

For instance, let us consider some of the ineconomies in our standard riveted construction—Why do we use angles for the tension members of a truss? Because we wish the one leg of the angle to give lateral stiffness to the truss and we need the other leg to fasten this

*Presented before Jan. 21, 1929, meeting of Philadelphia Section, A. W. S.
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one leg to our gusset plates. Again—why do we need gusset plates? So that we may have surface enough to collect the various rivets required to transmit the stress. Our handbooks tell us these rivets must not be placed too close together because the holes will weaken the plates too much if they are not spread a certain distance apart and anyway our riveting hammers cannot drive good heads if the rivets are too closely spaced. This required large surfaces at connections. Why do we use angles for the flange members of plate girders and for the web stiffeners? For the same reason we use angles for truss tension members. Why do we use angles instead of rods or bars for all classes of bracing work when a section in the shape of a cross would be more rigid and more economical? Because the mills do not roll a section in the shape of a cross and it would cost too much to rivet up two angles to make such a section.

Why don't the mills roll a cross section? Because there has been no demand for such a section. When we demand new sections our mills will furnish them. But until that time, it is very simple to weld the heels of two angles together making a very effective cross section and the cost is very slight.

Another section which would be of great value is a Tee section with a long stem. This would be very effective in a truss work for top and bottom chords. At the present time we take I-beams and split them making such Tees—also we could very nicely use sections with beveled or scarfed edges to deposit our welds into thereby saving the cost of grinding.

Why do we use solid rods in many cases whereas pipe would be more rigid for the same weight of material? Because of the difficulty and the cost of connecting pipe to structural steel frame work.

Now stepping over into the second class, why do we use carrier angles under fire-escape treads and checkered plate treads? Because we cannot safely and economically rivet such treads to the stringers without these angles.

Why do we use such heavy material for our posts, rails and balusters in ornamental rail construction giving us heavy handling charges, in the shop, in trucking and in freighting? Because the architects say they want a rail which looks substantial and so we need members of large diameters. But why not use hollow tubes or pipes instead of solid bars? Because the walls of such tubes are so thin that when we drill and tap our holes in them for fastening the pieces together there is not sufficient thickness of material to give us thread enough to make a safely rigid conection, and if we use tubes with walls thick enough to give us good long threads, it will cost as much—if not more—than solid bars would. But why all the countless holes which must be drilled and tapped and the numerous flat head bolts which must be used in ornamental rail construction? Because the architect would not like to have bolt heads exposed and it is usually difficult and expensive to rivet or pin these parts together.

Why ship metal stairs to a building in a knocked down condition and spend a tremendous amount for field erection where living expenses

must be paid? Why not make these up in large units in the shop where construction is cheaper and materially reduce the field erection expense? Because it would not look good to have the parts made up with round head rivets and countersunk head rivets are expensive and if flat head stove bolts are used, they would be sure to work loose in transit, and the stairs would be badly out of shape when received.

These are only a few of the questions which are constantly confronting one who is trying to save as much as possible in the construction of steel and iron work—but they show the line of thought necessary in the working out of details of construction if real economy is to be effected.

In studying this particular operation, consideration must be taken of all of the operations which are to follow—the details must be such as to make the lay-out work easy and rapid and as near fool-proof as possible—care must be taken to be sure that the detail worked up can be assembled readily—sometimes it is easier to make a drawing of a connection than to work up the connection itself.

In this connection I might state that care should be taken to have all the fussy machine work, such as notching, or coping punching for field connections (if field bolted) scarfing for welding, etc., done on the smaller pieces, leaving the heavier pieces as nearly as possible in thorough condition in which they are normally found in the stock pile. This can be done with a little thought in preparing the details of connections and will save a tremendous amount in the cost of shop labor. For instance, the usual under run and over run of plates need not be the nuisance it usually is if proper care is taken to provide for such allowances in the details of the connecting members.

Then there are the trucking and freight charges which must be considered. It is not wise to assemble a unit so large as to cause excessive transportation charges, sometimes these will offset the expenses of field erection.

Then the question must be constantly kept in mind—Can this be erected as I have detailed it—easily and economically?

In other words—the study of details must include a careful consideration of every operation to follow all down through the line, if the greatest economy is to be effected.

Layout and Assembly

The problem of laying out for welded construction is much simpler than for riveted work because of the greater simplicity of connections and hence the lack of details necessary on the shop drawings. The plainer a drawing is, the easier it is to follow it and the less chance there is of errors creeping in. This applies equally well to either the construction of structural steel or of ornamental or miscellaneous iron.

A study of the assembling and welding program must be made by the layer-out so that all pieces are properly prepared before they are assembled in place. It is easier to bevel an edge where welding is required *before* the piece is assembled in place than to discover it afterward.

In the assembly of either class of work there is one thing needed more than anything else and that is—*clamps*. Without a sufficient quantity of clamps a welding shop is seriously handicapped—*with* plenty of clamps, almost anything can be assembled.

Another large class of equipment needed is jigs. This is a very broad term and covers a multitude of types. There are in reality three main types of jigs required. These I have classed as 1—Forms; 2—Clamps and 3—Jacks.

The first class—"Forms"—includes those contraptions which are made up and used for the purpose of giving form or shape to the part to be welded. Each is carefully worked up so that the shape of the finished part will be true to the form called for on the plans but it is not usually necessary to put much care into the quality of the jig. The parts making up the jig are usually tacked together and no particular care taken to make a neat or especially strong job. It, in all probability, will not be used after this one job is completed and hence must not cost much.

The preparation of the second class of jigs is, however, an entirely different matter. I have grouped these under the heading of "Clamps" because the purpose of these jigs is to hold the assembled parts in place accurately and securely while they are being welded together. Care should be taken in working up these clamps to be sure that they are strong and substantial and as this takes time and costs money a study should be made to have these jigs suitable for future use. With a little thought such jigs can be made adjustable so they may be used in a variety of places. They should be relatively permanent.

The last group which I have called "Jacks" is, however, the most complicated and the most expensive—therefore require the most thought and study. Included in this group are jigs for jacking members apart, jigs for pulling members together, jigs for twisting members into place, and jigs for preventing members from twisting out of place—in fact. that vast number of corrective jigs which only those who are engaged in the welding of steel and iron work realize are necessary. These should be grouped into types and great care taken to make them permanent and also to be sure that they are applicable to a wide variety of uses.

One thing must be constantly in mind in the preparation of jigs—they must be easy to operate. It must not take so many men and require so much time to operate the jig that it will cost more to use it than to get along without it.

In connection with my reference to the use of corrective jigs, I think you might be interested in a set of five trash racks for the intake to a hydro-electric power plant which we made up a while ago. Each rack was made up of about 15 bars, 4 in x $\frac{3}{8}$ in, 20 ft. long, spaced about 3 in. on centers. Fastening these into position at about 4 ft. intervals were iron bars or angles notched so that they set up under and almost half way onto the long bars. At the point where each cross bar met a long bar, it was required that a continuous weld be made around the entire joint.

Well, we set up one rack, clamped everything very rigidly to some heavy beams and welded the joints all up completely. Not a sign of warping or twisting showed during our work. Then we started to take off the clamps and the rack began to twist and warp until, when all the clamps were off, we found a bow in the long bars of about 1½ in. and in the cross bars of about ¼ in.

We tried all manner of ways—hammering, jacking, etc.—to take out this warp but to no avail—it was there and it was there to stay. So we set the rack to one side and tackled a second. This time we set up all members as before but wedged all parts before clamping so that when completely clamped up there was a warp in the long bars of 1½ in. and in the short ones of ¼ in., as in the completed rack, but in the other direction. We thought that if we offset the parts the same amount they warped in the first rack that on welding, they would warp to the point where the rack would be straight when the clamps were removed.

Well, this resulted in a rack much better than the first one but not perfect. After several trials we found that it was necessary to put twice as much reverse warp in as the first rack had in order to have it come out right, with the result that the last of the five racks we have came out perfect.

This experimenting cost us a good deal of money but we learned something and something worth-while. We have used this principle several times since to good advantage.

I might state at this point that I believe one of the greatest things which our Society could do in the field of research would be to study into the problem of warping due to welding—so that it would not be necessary to *make* something in order to see how much it would warp so as to know how to counteract such warping. When there is a large quantity to be made the cost of making one unit wrong can be absorbed in the cost of the remaining units—but if there are only two or three to be made in all—or worse yet if there is only one to be made—it is a rather expensive procedure.

Welding

The man who assembles the work must have in mind the welding to be done and by a system of chalk marks or other notations advise the welder as to the exact location and size of each weld desired. The welder's time is valuable and he should not be required to study out for himself where to do the welding.

There should be someone thoroughly familiar with the job who will see to it after the welding is completed that all the welding is done which is necesary to give a good job. With a riveted proposition, if the holes are all placed in the middle to be riveted up, there is not much question but what the riveting gang will put in all of the rivets planned on. In fact, it may be necessary to say that they do not fill up a lot of field holes with rivets but where welding is done, it is not so easy for the welder to be sure that he has located all of the welds desired and unless the structure is carefully inspected before being painted, the chances are very great that it may leave the shop with some joints not fully welded.

Erection

Regarding the shipping question there are such things to be considered as size, weight, crating problems, etc., all of which will affect the amount of shop work to be done and the amount left to be completed in the field. The same thing applies to the erection problem and must be carefully considered from the very beginning of the project.

I would like to state right here that I believe that the greatest economy will come when all structures are erected entirely in the field using what I call the "saw, hammer and nail method"—such as is used in timber construction. We followed this method in the construction of the building in Maine referred to previously All material was sent direct from the mill to the job and cut, fitted and erected entirely in the field, the burning torch being the "saw," the welding outfits being the "hammer and nails." Not a hole was made and not a hole was needed. Why should there be? You do not usually use holes in timber construction—why are they necessary in steel work?

Arc-Welded Steel Construction Used in Florida Packing Houses

A. F. Davis†

IN central Florida there have been erected recently fifteen buildings of arc welded steel construction. Most of these are citrus packing houses, scattered throughout the fruit growing districts. The frames of these structures are all of the clear span welded steel arch type, designed and erected by The Arch Engineering and Construction Company, R. L. Graveley, owner, Orlando, Fla.

The largest of these buildings, in fact it is the largest citrus packing house in the world, is owned by the Dr. P. Phillips Co. The building is 117 ft. wide by 202 ft. long, and due to the welded steel arch design there are no supporting columns in the interior of the structure which contains 200 tons of structural steel.

This building was under process of construction when the two hurricanes spread disaster in Florida in August and September of last year. In the first hurricane the wind blew down the partially completed rear masonry wall, went through the building and blew out the front masonry wall. The arc welded steel super-structure remained intact withstanding the terrific strains imposed upon it by the force of the hurricane. Again in the second hurricane, which was more severe than the first, the strength and rigidity of the arc welded construction was tested severely but the steel framework remained in perfect alignment. Several other buildings of the same design and construction, completed before the hurricanes, survived though adjacent buildings of other types of steel construction were badly twisted out of shape. With the possible exception of a severe earthquake no greater test of the strength and rigidity of arc welded steel construction could be given than was imposed by the Florida hurricanes.

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Two buildings used for fruit packing houses have been built for the Seaboard Airline Railway, one 80 ft. wide by 225 ft. long, at Winter Garden, Fla., and the other at Leesburg, Fla. An interior view of the latter building is shown in Fig. 1. This particular building is 74 ft. wide by 217 ft. long, the arches spanning the entire width.

The steel arches are made up of structural channels cut to form an arch when butted end to end. They are then fabricated literally into

FIG. 1. INTERIOR VIEW OF PACKING HOUSE

a one piece steel arch by the electric arc welding process. The entire fabrication of the arches is completed on the ground, then the arches are raised into position and the entire structure thus formed tied in by welding channel purlins to the arches. The framework of the monitor, shown in Fig. 1, is composed of angles and channels fabricated by arc welding. The steel sash frames are also arc welded in place, in fact, no rivets, bolts, or screws are used in the entire fabrication and erection of these steel arch buildings.

All the fabricating work on these buildings is done in the field, all connections being made by the electric arc welding process.

The simplicity of the novel design due to the elimination of all trusses and other forms of roof bracing is an economic factor which should favor this particular type of arc welded construction for future buildings. In the last year three large all steel fireproof hangars for aeroplanes were erected at the municipal airport for the city of Houston, Tex. These hangars were also of welded steel arch construction.

Resistance Welding*

H. A. WOOFTER†

THE art of joining metals is one of the oldest known to man. Pieces of welded iron have been found in the ruins of ancient Tyre, Ninevah and Babylon. The Egyptians used soft welded iron, but had no knowledge or means of hardening it. They had a means of hardening copper, however, which is now a lost art, and this metal was used to carve the hieroglyphics, the obelisks and walls and tombs of the Pharaohs.

The greatest, and most amazing piece of welding handed down to us from antiquity is found at the ancient city of Delhi, India, in a temple yard. It is a welded iron pillar over 62 feet long, and now about 16 in. in diameter, although it was doubtless 20 in. in diameter when it was made over 2000 years ago. The shaft projects 22 feet above the surface of the ground, and extends into the earth more than 40 feet. It was apparently welded into one piece from blooms weighing about 70 pounds each. The welds are as perfect as if they had been made with our most modern gas or arc welding equipment, and yet they must have been forged by hand. There were about 940 blooms welded one at a time, to make up this 66,000 pound pillar. So far as we know, their only means of welding a 70-pound bloom onto another and larger piece was to heat both pieces to welding temperatures and sledge them into place by hand. All labor was performed then by naked slaves.

For thousands of years the blacksmith with his primitive knowledge and equipment could weld iron only of all of the ferrous group of metals and alloys, and only gold in all the non-ferrous group. It has been less than 200 years that steel could be welded by the blacksmith, and then only by the use of fluxes, and high carbon steel has been welded only within the last half century.

With the advent of gas and electric welding, it became possible to weld together all of the ferrous group, all of the non-ferrous group, and anyone of the ferrous to anyone of the non-ferrous group. Practically all of this development has occurred within the last 40 years.

Broadly speaking, "welding" is joining two or more pieces of metal by causing cohesion of the molecules of the pieces. The best modern methods of welding are those in which cohesion is effected by means of high temperatures produced by gas or electricity. Many metals which cannot be welded by hammering may be welded by the new processes. Metals are most easily welded when in that degree of plasticity between the molten and the solid states; hence, those metals which remain plastic the longest while cooling are the easiest to weld, and vice versa. So recently as 1910, it was considered impossible to weld aluminum because it would lose its plastic state before it could be gotten from the fire to the anvil to be struck with a hammer. Today not only aluminum but

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practically every kind of element or alloy, excepting tin, can be electrically welded by the resistance process. I am sometimes asked why tin is the only metal that cannot be welded. It can be welded for the instant, but it immediately begins to suffer from an inherent quality commonly called skin disease, and the next day after welding will fall apart in the weld. Successful welding by any method depends almost entirely upon three factors, namely, flow, cohesion and temperature, but in resistance welding we must add a fourth factor, namely, pressure. The metal must tend to *flow* at some critical *temperature*, so that it will *cohere* when *pressure* is applied. Welding temperatures vary for each element and alloy because each of their melting points are different. In fact, the welding temperature varies widely sometimes, for the same element or alloy, as, for instance, wrought iron melts at 2900 deg., malleable iron at 2500 deg., cast iron at 2400 deg., and pure iron at 2760 deg. Likewise, mild steel melts at 2700 deg., medium steel at 2600 deg., and hard steel at 2500 deg.

The best welding temperature for most metals is usually about 100 deg. below their melting points, at which time they are in a plastic state. A few metals, however, such as lead or cast iron, do not become plastic until their melting temperatures are reached, hence they require quick and careful handling to secure good welds.

In this article we will consider Resistance Welding only, since it is the original Electric Process, from which all the various forms of Spot, Butt, Flash, Pressure Contact, Point, Cross Wire, and other classes of welding have evolved.

Many metals and alloys must be welded almost instantly in order to secure the desired kind of welded joint. Notable examples of these are (1) copper, (2) brass, (3) aluminum, (4) duraluminum. For instance, (1) copper, if heated slowly to welding temperature will undergo certain well defined chemical changes. It will absorb oxygen from the air, thus forming at least two oxides, namely, cuprous oxide, Cu_2O, a red substance sometimes used in making artificial rubies, and cupric oxide, CuO, a green substance sometimes used in the manufacture of artificial emeralds. Furthermore, copper usually contains sulphur, and when this element occurs there are always one and sometimes two sulphides formed, namely, cupric sulphide, CuS, and cuprous sulphide, Cu_2S. These chemical substances are often used in dyes and poisonous paints for hulls of ships. Now while these artificial gems may be desirable in Woolworth's Five and Ten Cent Stores, and while these poisonous dyes and paints are desirable on hulls of boats and ships below the water line, they are each and all very undesirable in a copper weld, for copper is the most sensitive of all the elements to outside influences. For instance, 1/16 of 1 per cent of silicon mixed with copper cuts the electrical conductivity down to 72 per cent. One per cent of silicon makes the copper too porous to test. One per cent of phosphorous in the copper reduces its conductivity to about 40 per cent. Four per cent tin and 2 per cent zinc in copper reduces its conductivity to 20½ per cent. Ten per cent tin and 2 per cent zinc in copper reduces its conductivity to 11½ per cent, or approximately the same as ordinary cast iron. Thus you can realize the necessity of precluding all outside influences when making

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copper welds, especially when it is to be used for electrical purposes. Each and all of the above named impurities will cause a brittle weld known as red short, that cannot be drawn through reducing dies, and sometimes cannot even be forged or rolled.

By the resistance process the ends of the rods or bars are brought together while cold under heavy spring or weight pressure, the current thrown on, the stock is instantly softened at the joint, the metal yields to the pressure, and pushes up, the current being automatically interrupted. It is only from .2 to 1.5 seconds from the time the current is thrown on until it is cut off and the weld is completed. It is readily apparent that there is not sufficient time for the formation of oxides or sulphides, and the weld is so ductile that it may be drawn through reducing dies into small wire. Sometimes the welded stock is drawn through seven consecutive dies of diminishing diameter in one operation. Now let us see what would have occurred if considerable time and some deoxidizing agent such as phosphorous had been used in making the weld. In the first place, oxides and sulphides would have formed in the weld. In the second place, phosphorous when used as an enveloping flux hardens the weld, making it brittle, so that it cannot be drawn or rolled. One per cent of phosphorous in copper reduces its conductivity 52 per cent, and such wire, even if it could be drawn, could not be used for electrical purposes, for it would cause a hot spot in the coil, and being inferior in conductivity to aluminum wire, which is 63 per cent as good a conductor as copper, as against the 48 per cent of the copper phosphorous wire. In order for the arc or gas welder to weld copper, he invariably uses phosphorous welding rod, with the results of a red short, low conductivity weld in which the metal has undergone certain distinct chemical changes.

(2) *Brass*

For another example, brass is most easily welded by the resistance method because of its quickness. It is said that there are about 2500 possible alloyed brasses, fifty of which are produced by the brass mills every day. Take an average grade of yellow brass, however, composed of about 66 per cent of copper and 34 per cent of zinc. Copper melts at about 1981 deg. and zinc at 780 deg. and boils off in a blue white cloud at 1725 deg. Now, if the brass is melted slowly as in a forge, or by a flame, the zinc will all have melted or volatilized from the vicinity of the weld before the copper has reached its melting temperature. But when this same material is welded in 0.1 of a second by the resistance process, there is a sharp report like a pistol, and the weld is made with practically no volatilization. Cast brass (red) usually has about 85 per cent copper, 5 per cent zinc, 5 per cent lead and 5 per cent tin, and welds about the same as yellow or drawn brass.

One more example: Aluminum comes principally from two ores, namely, Bauxite and Cryolite, and is made in two principal grades, namely, No. 1, which is 99.55 per cent aluminum, 0.30 per cent silicon and 0.15 per cent iron, and No. 2, which is 96 per cent aluminum, 2 per cent silicon, and 2 per cent iron. When aluminum is melted slowly in air as, for instance, by a gas flame or electric arc, it forms an oxide known as alumina. This alumina is granular like sand and surrounds or envelops small masses of the metal. Now, as alumina does not melt until it

reaches 5000 deg., and aluminum itself melts at 1215 deg., you can readily see why it is necessary for the arc and gas welder to use fluxes, deoxidizers, etc., to envelop the weld and try to preclude oxygen to prevent the formation of alumina in the weld. But by the instantaneous resistance process, there is a pistol-like report, similar to that occurring in the welding of brass, and the weld is made. This kind of weld shows a clear break, same as any other part of the metal, with no trace of the dangerous, treacherous alumina. It is also easy to weld duralumin, monel metal, nickel, nickel steel, or practically any element or alloy, except tin.

Duralumin

If it is attempted to weld this metal by any slow process of heating, practically the same chemical and physical changes take place as in the welding of aluminum. Welds so made must always be annealed for a period of from five to seven hours to prevent their deterioriation and failure due to hydroscopic absorption either from the atmosphere itself or when exposed to moisture. The failure, with a large loss of life, of the first dirigible built by Germany for the United States was due to the deterioration of gas welds in the duralumin framework, it not being know at that time that annealing was an absolute essential. With the Resistance Method, however, the weld is made practically instantly, and it is not necessary to anneal the weld unless the very maximum strength of the metal is required. By annealing resistance welds in duralumin, a tensile strength is secured in a ratio of 61 : 55 over that of the unannealed weld. No deterioration takes place in the unannealed weld due to hydroscopic absorption, since the mechanical pressure applied at the instant of weld solidifies or condenses the metal, whereas in other processes, the weld is spongy, leaving minute pores for the absorbing and holding of moisture.

Monel Metal

Monel metal is welded very similarly to ordinary steel as far as projection, mechanical pressure and time are concerned, but it takes about 25 per cent more power to weld it than the same size of steel. This metal lends itself very readily to seam welding, thus making it a very valuable metal for ice cream and milk containers, battery jars, etc., since the metal is impervious to rust and is not acted upon by any except the strongest acids.

Special Metals

Several special metals are welded very readily by the resistance process as, for instance, stainless steel, which is made by alloying from 16 per cent to 20 per cent of chromium with the steel. If it is attempted to weld this metal by any process requiring considerable time, porosity always appears, due to the different temperatures of melting of chromium and steel. However, when welded instantly, it makes a beautiful weld. It is now being used for the stems of automobile valves, and is welded on to the cast iron head by a resistance process known as the Pressure Contact Weld. Many other special metals too numerous to mention can be easily welded by the Resistance Process. It is only necessary to procure a specimen of the metal large enough to make a few experimental welds in order to determine the best set-up for the particular job at hand.

Some manufacturers have seen the great possibility of the resistance process in upsetting brass and bronze rods as, for instance, in the case of gate valve stems. It was formerly necessary to turn down a large bar in order to make the thrust collar on the valve stem. Since some of these stems are 10 feet long, you can see the enormous loss of labor and material that occurred when making these gate valve stems by the old process. Now, however, the stem is placed in a resistance welder with the point to be heated between the platens, current is turned on, and at the first showing of pink color the platens are pushed up, making an upset from which the thrust collar is turned, thus saving any machining down along any other parts of the stem. These upsets are made without breaking the skin of the original rod, and when one of these upsets is cut in two, polished etched and micro-photographed the structure of the metal is practically the same as at any other point of the rod, except that its density has been somewhat increased due to the mechanical pressure applied, and this is considered an added advantage rather than a detriment.

Finally

The chief advantage of resistance welding, in the final analysis. is the great production that it makes possible, as in case of small rings and buckles at 75 per minute, to automobile rims from 8 to 18 per minute. The marvelous savings it accomplishes help largely to enable the common people of today to have and enjoy many of the things that were thought to be the luxuries of the rich only, just a few years ago.

Recent Developments in Atomic Hydrogen Welding*

By PETER P. ALEXANDER†

PERHAPS, as engineers, you are not interested in the theory of atomic hydrogen welding process, but you will be interested in the many things that can be accomplished by this new method of welding.

The apparatus used is very simple, consisting of two tungsten electrodes and an electric arc, established between them, and everything is shielded by a flame of hydrogen. The torch used for welding is simplicity itself—support to hold the electrodes, and two tubes directing a hydrogen flame around the electrodes. All energy supplied to the weld is from an electrical circuit. The gas serves only to shield the electrodes, to protect the metal from oxidization, and to increase the efficiency of the arc.

If the arc of the same current and length be maintained in an atmosphere of nitrogen, the potential drop along the arc core will be about 10 volts per centimeter. When we replace nitrogen with hydrogen, the potential drop will be increased fifteen times, so that by blowing hydrogen toward this arc, the efficiency is increased. In this way it was possible, for the first time, to use the indirect arc in a very efficient way.

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†Thomson Research Laboratory, General Electric Co.

There are several processes using the indirect arc for welding, but they are inefficient. It is only when air was replaced by hydrogen, the efficiency of the process of indirect arc welding was increased to such a degree that now it is a very successful process.

All the energy is coming from the electrical circuit, so it is essentially an electrical process of welding, and yet it possesses all the characteristics of a gas welding process. This process is adaptable to the welding of thin materials.

Another field of its application is welding of special alloys and low melting point alloys. The use of special alloys is increasing every day.

Since in the atomic hydrogen process the electrodes are non-consuming, we can add the material to the welded plate from a special welding rod of any desired composition. If you attempt to do so with direct arc, you will find that if the electrode has high chromium or carbon, it will be almost impossible to maintain an arc. However, if the arc is maintained independently, you can use this rod quite easily.

The importance of aluminum and other light alloys is increasing. It is almost impossible to weld these alloys with the direct electric arc. However, they can be welded with gas. On account of very low melting point of these alloys when arc is established between the electrode and the plate, much of the metal is vaporized but with indirect arc, the temperature may be easily kept within the desired limits.

Hydrogen protects the alloys from oxidization. The greatest obstacle for welding aluminum is the formation of aluminum oxide, which prevents the metal from running together. With atomic hydrogen welding, it is possible to weld aluminum under certain conditions without this danger of formation of aluminum oxide, and it is even possible to reduce the aluminum oxide already formed to its metallic state. Still, it is not practical at the present time to use the atomic hydrogen welding process for welding thin aluminum sheets, without fluxes on account of the desire to maintain a high speed of welding the thin materials. So that in practical applications of the torch for welding thin aluminum sheets, additional fluxes are used.

CURRENT WELDING LITERATURE

Acetylene Meeting Discusses Pipe Welds. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 21, pp. 54-56. Leakless joints said to warrant adoption even at increased cost. Improvel welding rod produces non-porous welds in alpha brass pipe. Expansion in use of acetylene. Industrial and refrigerating piping. Modern Swiss welding practices.

Action-at-Law Concerning Electric Welding Machine Patent. The Welding Journal (March, 1929), Vol. 26, No. 306, p. 82.

Airplane Welding Jigs. J. F. Hardecker. Acetylene Journal (April, 1929), Vol. 30, No. 10, pp. 409-410. Properly designed jigs are the solution of many production welding problems and welding jigs are usually simple in construction.

Aluminum Vies with Steel for Chairs. F. L. Prentiss. The Iron Age (New York, March 14, 1929), Vol. 123, No. 11, pp. 729-732. Manufacture of furniture of alloy metal put on production basis at the Buffalo plant of U. S. Aluminum Company.

*Presented to the Industrial Heating Conference, M. I. T., February 28, 1929.
†Thomson Research Laboratory, General Electric Co.

176 Arc-Welding Nickel-Chromium Alloys. G. A. Maurath. The Welding Engineer (March, 1929), Vol. 14, No. 3, pp. 49-50. The most satisfactory practice in welding these resistant alloys is to reverse the polarity and buck the current. Heavy single beads should be avoided.

177 Arc-Welding Practice on a Large Hotel Building. H. M. Priest. Engineering News-Record (March 28, 1928), Vol. 102, No. 13, pp. 490-492. Placing column splice plates and seat angles a constant distance from column webs effects economies. No overhead welding.

178 Automatic Electric Welding Apparatus. A. M. MacFarland. Off. Gaz. (Dec. 18, 1928), Vol. 377, p. 655.

179 Better Fabricating Results by Arc Welding. Electrical World (April 13, 1929), Vol. 93, No. 15, p. 742. Elimination of noise and intricacies of design accompany simplification of machines. Weight of material reduced without losing strength. Experimental work made easier.

180 Brass Welding and Brazing. Acetylene Journal (April, 1929), Vol. 30, No. 10, pp. 422-423. Investigator finds that oxidizing flame is helpful in getting better brass welds and special alloy rod is recommended for brazing.

181 Chicago Section A. W. S. Meets with Steamfitters to Discuss Industrial Pipe Welding. Acetylene Journal (April, 1929), Vol. 30, No. 10, p. 425.

182 Crew for Pipe Line Welding Requires About 17 Min. H. M. French. Oil Field Engng. (Feb. 1, 1929), Vol. 5, pp. 16-17.

183 Design of Welded Joints for Aircraft. J. B. Johnson. The Welding Engineer (March, 1929), Vol. 14, No. 3, pp. 35-38. Economical production is greatly facilitated by use of jigs for standard assemblies. Welded joint solves problem of reducing weight of tanks.

184 Development and Progress of Mechanical Gas Welding. J. L. Anderson. Acetylene Journal (April, 1929), Vol. 30, No. 10, pp. 411-417. As a production process this method has the combined advantages of very high welding speed and an exceptionally ductile weld. Mechanically welded flat sheets and plate. Mechanical welding of heavier material. Mechanical weld reinforcement. Mechanical welding speed limited by machine design.

185 Electrically Welding Pipe Line of 205 Miles in Field. The Iron Age (April 4, 1929), Vol. 123, No. 14, p. 977.

186 Field-Welded Pipe Hung on Canyon Walls Carries Water Supply. C. J. Ullrich. Engineering News-Record (March 21, 1929), Vol. 102, No. 12, pp. 465-467. Permanent anchors in cliff supported platform for welders. Alignment followed topography with angles at every joint.

187 Fusion Facts, March, 1929, Vol. 2, No. 6. Pile Driver Built to Order. Aluminum Welding of Motor Cases Without Preheating. The Whys of Welding. Influence of the Elements Upon the Physical Properties of Iron and Steel. Welding Utilized in Factory Construction.

188 Garage Has Welded Framework. The Welding Engineer (March, 1929), Vol. 14, No. 3, pp. 39-40. Welder uses scrap pipe to good advantage in construction of two-car garage, which he guarantees to be hurricane proof.

189 Hospital Addition Erected Silently. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, p. 58. Steel structure addition fabricated in field by arc welding.

190 Hospital Addition Erected Silently. The Welding Engineer (March, 1929), Vol. 14, No. 3, pp. 51-52. Patients are undisturbed and operations are performed while steel structure is fabricated in the field by arc welding.

191 How Procedure Control Welding Originated. G. O. Carter. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 46-47. Rapid construction of overland pipe lines magnified all managerial problems found in production welding. Early work on pipe joints. Difficulties encountered in scattered crews.

192 Impurities in Carbide of Calcium. The Welding Journal (March, 1929), Vol. 26, No. 306, pp. 86-88.

193 Managerial Understanding of Welding. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 60-61. Development by procedure control permits executives to apply principles of production engineering. Testing operators' ability. Selection of material. Design and layout of welded joints. Preparation for welding. Welding technique. Inspection and testing.

194 Major Provisions of an Arc Welding Specification. F. P. McKibben. Engi-

Company.

neering News-Record (March 14, 1929), Vol. 102, No. 11, pp. 425-427. Adaptable to general use. Has been utilized in present form on six recently welded buildings.

Metal Arc Welding. The Welding Journal (February, 1929), Vol. 26, No. 305, pp. 48-52.

Notes on Electric Welding. J. Lyall. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 43-44. Water, steam or airtight repairs. Structural steel welding. Boiler welding.

Oxy-Acetylene Tips (March, 1929), Vol. 8, No. 7. Advertising for the Welding Shop. An Improved Bronze Welding Rod. Leakproof Hot Air Furnaces. Service Connections for Gas Mains. Design of Welding Jigs and Fixtures. A Cleverly Designed Oil Feeding System. Another Proof of Effectiveness. When the "Mud-Buster" Was Broken.

Oxy-Acetylene—Unlimited. Walton Smith. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 41-42.

Oxy-Acetylene Welding in the Foundry. G. F. Wieser. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 68-69. The welding torch is an important factor in assisting the up-to-date foundryman to keep costs down, to make deliveries of sound, well-finished castings when promised.

Pipe Line Welding from the Oxy-Acetylene Viewpoint. Le Roy Edwards. Pipe Line News (March, 1929), Vol. 1, No. 4, pp. 3-7.

Practical Hints on Electric Welding. J. Lyall. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 48-49 and 67. With special reference to engine bar frames, engine plate frames and tanks.

Practical Methods of Oxy-Acetylene Welding. L. A. Cowles. Power Plant Engineering (April 15, 1929), Vol. 33, No. 8, pp. 482-483. Part 1, Use of the torch is becoming a necessary trade for the engineer. Precautions and directions are given for use of equipment.

Process and Apparatus for Welding Plates. C. Schaer. Off. Gaz. (Dec. 11, 1928), Vol. 377, p. 629. Edges are beveled, and finished edges turned over.

Proving the Merits of Structural Welding. The Welding Engineer (March, 1929), Vol. 14, No. 3, pp. 41-43. Typical structural joints are welded and tested to fracture before gathering of architects, engineers and contractors at University of Detroit.

Recent Developments in Atomic Hydrogen Welding of Alloys. The Iron Age (April 4, 1929), Vol. 123, No. 14, p. 949.

Redesign for Production Welding. J. F. Lincoln. The Iron Age (March 14, 1929), Vol. 123, No. 11, pp. 737-739. Methods outlined whereby the process can be instituted by manufacturers of machinery or metal products.

Report on Pilot Tests Conducted for the Structural Steel Welding Committee of the American Bureau of Welding at the University of Toronto. P. Gillespie and others. University of Toronto. School of Engng. Research. Bulletin No. 8 (1928), pp. 35-72.

Shop Truck Made of Welded Steel. The Iron Age (April 4, 1929), Vol. 123, No. 14, p. 956.

Strengthening of Euchuca Bridge by Electric Welding. W. D. Chapman. Inst. of Engrs. Australia Trans. (January, 1929), Vol. 1, pp. 9-18. An account of the widening and strengthening of a pedestrian and railroad bridge built in 1876 across the Murray River at Euchuca.

Strengthening of Euchuca Bridge by Electric Welding. W. D. Chapman. The Journal of the Institution of Engineers of Australia (February, 1929), Vol. 7, No. 2, pp. 57-60.

Structural Steel in Machine Design. Welding in Redesign Engineering. The Welding Journal (March, 1929), Vol. 26, No. 306, pp. 80-81.

Structural Welding Experimental Study. P. Gillespie. Canad. Engr. (Jan. 15, 1929), Vol. 56, pp. 143-6.

The First Welded Railroad Frame Bridge, Chicopee Falls, Mass. O. Bondy (Die erste geschweisste Eisenbahn-Fachwerk-Brucke Chicopee Falls, Mass.) Schw. Bauztg. (Jan. 12, 1929), Vol. 93, pp. 15-16. Arc-Welded Steel.

The More Important Types of Jig. P. Holland. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, pp. 50-53. Supplying the welder with simple mechanical jigs offers a means of quicker, more regular and economical production of perfect welding work.

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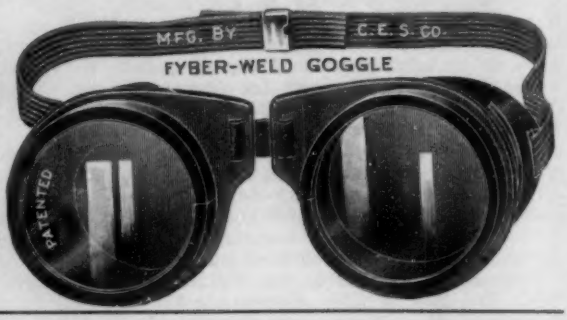

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